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Effects of intermittent fasting (time-restricted eating) for 30 days on body weight, visceral fat, and muscle mass in adult workers

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Abstract

Obesity among workers is an important occupational health concern because of its association with cardiometabolic risk and productivity loss. Time-restricted eating (TRE) 12:12 is a mild intermittent fasting protocol that limits food intake to a 12-hour eating window and may be feasible for workplace implementation. This study aimed to evaluate the effect of a 30-day TRE 12:12 intervention on body weight and body composition among adult workers. A quasi-experimental one-group pretest–posttest study was conducted among adult workers in Semarang, Indonesia. Participants followed TRE 12:12 for 30 days without prescribed calorie restriction. Body composition was assessed before and after the intervention using bioelectrical impedance analysis. Changes in outcomes were analyzed using paired-samples t-test and Cohen's d, while adherence and participants' perceptions were summarized descriptively. After 30 days, body weight decreased by 2.38±1.97 kg, body mass index (BMI) by 0.90±0.70 kg/m², body fat by 1.08±1.23%, visceral fat level by 1.12±0.72, and waist circumference by 5.82±3.37 cm, with all changes statistically significant ($p \leq 0.001$). Skeletal muscle mass increased slightly by 0.36±0.55% ($p=0.008$), which was interpreted as muscle preservation rather than meaningful muscle gain. Overall adherence was high (98.1%), reported side effects were mild, and most participants perceived the intervention as beneficial. This study highlights that TRE 12:12 was associated with short-term improvements in body weight and body composition among adult workers, particularly reductions in visceral fat and waist circumference, while preserving skeletal muscle mass. Further studies with larger samples and longer follow-up are needed to confirm its effectiveness and sustainability in working populations.

Keywords: Time-restricted eating, intermittent fasting, visceral fat, obesity, workers

Introduction

Obesity and overweight have now grown into one of the most serious public health crises at the global level, and the trend shows no sign of slowing [1]. It is projected that by 2035 more than 1.53 billion adults worldwide will be living with obesity, equivalent to roughly 54% of the total global adult population [2]. This figure is far more than a statistic—behind it lies a massive economic burden, with an estimated financial impact reaching US$ 4.32 trillion from the various health consequences that follow [1]. Obesity is not merely an aesthetic concern; it is a primary risk factor for a range of deadly non-communicable diseases (NCDs), from type 2 diabetes mellitus and cardiovascular disease to several cancers, and it remains a major contributor to disability and premature death worldwide [2-3].

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In Indonesia, the situation is no less alarming. Adult obesity prevalence more than doubled—from 10.5% in 2007 to 21.8% in 2018, according to Basic Health Research (*Riskesdas*) data [4], and remained high at 21.6% in the 2022 Indonesian Nutritional Status Survey [5]. More worryingly, the rate of increase in body mass index (BMI) is higher in women than in men and central obesity in urban areas leapt from 28.0% in 2007 to 57.2% in 2018 [4]. The geographic disparities are striking: districts in Java and Bali recorded obesity prevalence 29–60% higher than the Papua, Maluku, and Nusa Tenggara regions, a gap that mirrors socioeconomic inequality and differing degrees of urbanization [6].

Within the working population, obesity is not just an individual health problem—it has become a strategic concern in Occupational Health and Safety (OHS), with tangible and measurable economic consequences. Workers with obesity show a 66% higher rate of absenteeism and markedly greater on-the-job productivity loss (presenteeism) than their normal-weight colleagues [7-8]. Estimates from the United States indicate that obesity adds 3.0 days of absence per employee each year, with productivity losses of US$ 271–542 per individual—pushing the total national loss to US$ 13.4–26.8 billion [9]. A more comprehensive 2023 analysis put the combined burden of obesity and overweight on the American workforce at US$ 425.5 billion, averaging US$ 6,472 per employee [7]. The picture worsens in workers with sedentary patterns or light physical activity, where the lack of movement deepens energy imbalance and accelerates the build-up of cardiometabolic risk [8].

Modifying dietary patterns has proven to be the most effective weight-management strategy, particularly for workers who have little time for regular, intensive exercise [10]. One approach drawing growing attention is intermittent fasting (IF)—an eating pattern that structures cycles of eating and fasting without dictating the type or amount of food, focusing instead on the timing of intake [11]. Physiologically, IF drives a metabolic shift from glucose to fat as the primary fuel through ketogenesis, improves insulin sensitivity, activates cellular autophagy, and helps tune metabolic circadian rhythms [11]. IF has also been shown to reduce oxidative stress and systemic inflammation, and restore gut microbiota composition—all of which feed into a better overall cardiometabolic profile [12].

Among the IF variants studied to date, the main protocols include alternate-day fasting (ADF), the 5:2 diet, and time-restricted eating (TRE). ADF and the 5:2 diet involve fasting or marked energy restriction on specific days, whereas TRE restricts food intake to a defined daily eating window. TRE protocols are commonly described by their daily eating-to-fasting ratio, such as 16:8, 14:10, or 12:12. Among these TRE protocols, the 12:12 method, which limits eating to 12 hours and fasting to the remaining 12 hours, is considered the gentlest approach and may offer strong adherence potential without requiring drastic lifestyle change [11,13]. A recent meta-analysis reported that TRE produces meaningful weight loss (mean difference: −1.93 kg) and significant body-fat reduction (effect size: −0.20) in overweight and obese individuals [13]. A study among middle-aged women in Taiwan found an average 3.2 kg weight loss after an 8-week TRE intervention alongside clear improvements in body composition [14]. A recent randomized controlled trial found that TRE 12:12 could reduce fat mass without sacrificing lean body mass—a critical edge over conventional calorie restriction, which often costs muscle [15].

Yet despite the accumulating evidence on IF, a real gap remains in the literature—specifically around implementing TRE 12:12 in the Indonesian working population. Most available studies focus on stricter variants such as TRE 16:8 or ADF, and are run in clinical groups with particular metabolic conditions rather than in healthy, overweight adult workers [16]. Comprehensive data on body composition parameters—fat percentage, visceral fat, and muscle mass—in this context are scarce. At the same time, the adherence and feasibility of fitting IF into the rhythm of Indonesian work life also have not been well documented [16]. Given the distinctive eating patterns, work culture, and socioeconomic backgrounds of Indonesian workers, which differ from Western populations, strong local empirical evidence is needed to craft genuinely evidence-based OHS health-promotion policy.

The present study therefore was conducted to analyze the effects of a 30-day TRE 12:12 intervention on body weight, BMI, and body composition—fat percentage, visceral fat, muscle mass, and waist circumference—in adult workers. This study simultaneously evaluated adherence and participants' perceptions of the intervention as indicators of how feasibly the program can run in an occupational health setting. This study is expected to provide strong, context-specific evidence to support recommending TRE 12:12 as an effective, implementable weight-management strategy that can be folded into OHS promotion programs—both to prevent NCDs and to improve the productivity and well-being of Indonesian workers.

Methods

Research design and setting

This study used a quasi-experimental one-group pretest–posttest design to evaluate the effectiveness of the TRE 12:12 intervention on body weight and body composition among adult workers. Although the absence of a control group makes this design vulnerable to threats to internal validity, this approach remains relevant and widely used in real-world health-intervention evaluations where randomization is not always feasible [17]. The study was conducted at a workplace occupational health clinic serving employees of an energy-sector company in Semarang, Central Java, Indonesia, over 30 consecutive days, from June 1 to June 30, 2025. The target population comprised all adult workers aged 18–60 years attending the clinic, regardless of baseline BMI. BMI categories were defined using the Asia-Pacific criteria for descriptive classification only [18].

Participant criteria

Participants were considered eligible if they were permanent employees of the clinic with active employment status, were aged 18–60 years, were not currently enrolled in another weight-loss program, and had no uncontrolled acute or chronic metabolic diseases, including type 1 diabetes mellitus, thyroid disorders, or chronic kidney disease. Participants were excluded if they were pregnant or breastfeeding; had a history of eating disorders or major psychiatric disorders requiring medication; were using medications that could affect metabolism or body composition, such as systemic corticosteroids or weight-loss drugs; were unable to undergo bioelectrical impedance analysis (BIA) because of pacemakers or metallic implants; or had protocol adherence below 83%, defined as completing fewer than 25 of the 30 intervention days.

Sample size and sampling

Participants were recruited using purposive sampling from a finite pool of employees at the clinic. Eligible employees were identified through clinic management and invited to participate voluntarily. Of the 23 employees who were invited to participate, 21 agreed, yielding a response rate of 91.3%; two employees declined for personal reasons. The final sample size was therefore 21 participants. No formal a priori sample-size calculation was performed. However, based on standard power formulas for paired-samples t-tests, a sample of 21 participants was estimated to provide 80% power at $\alpha=0.05$ to detect moderate-to-large within-participant effects, approximately corresponding to Cohen's $d \geq 0.60$ [19].

Variables and study outcomes

Baseline demographic characteristics were collected, including age and sex. Physical activity of the participants was assessed using single-response questionnaire items on exercise frequency and exercise intensity. Exercise frequency was categorized as rarely/never, 1–2 times, 3–5 times, or ≥6 times per week, while exercise intensity was categorized as light or vigorous.

The primary outcomes measured in this study were: (1) body weight (kg); (2) BMI (kg/m^2); (3) body fat percentage (%BF); (4) visceral fat level; (5) skeletal muscle mass percentage (%); and (6) waist circumference (cm). Body-fat percentage and visceral fat were assessed because BMI alone does not capture adiposity or fat distribution [20]. All anthropometric and body-composition measurements used the Omron Karada Scan HBF-701, a tetrapolar bioelectrical impedance analysis (BIA) device with a hand-to-foot configuration validated for adult populations [21]. The device was calibrated to manufacturer standards before data collection. Height was measured with a portable stadiometer (precision: 0.1 cm), and waist circumference with a non-elastic tape at the midpoint between the lowest rib and the iliac crest at the end of normal expiration, following standardized waist-circumference measurement procedures [22]. All measurements were taken in the morning (07:00–09:00), after at least an 8-hour fast and after voiding, with participants in light clothing and without shoes or metallic accessories, to minimize BIA variability.

The secondary outcomes assessed in this study were adherence and participants' perceptions of the intervention. Adherence was quantified using participants' daily meal-time logs as the proportion of completed intervention days out of the 30-day intervention period and was cross-checked against self-reported adherence. Participants' perceptions were assessed using a structured post-intervention questionnaire consisting of single-response items covering perceived difficulties or side effects, subjective energy level, sleep quality, eating quality, meal frequency within the eating window, perceived stress, and perceived benefits of the intervention. Because all questionnaire items were categorical, responses were summarized descriptively as frequencies and percentages, and no composite score was computed.

Intervention procedures

The procedure began with recruitment and informed consent for eligible respondents. After consenting, all participants underwent baseline (pretest) measurement. The TRE 12:12 intervention asked participants to confine eating to a 12-hour window—for example, 07:00 to 19:00—and fast for the following 12 hours. During the fasting window, participants could drink water, unsweetened tea, or black coffee without sugar, but no caloric foods or beverages. During the eating window, they kept their usual dietary patterns with no restriction on food type or quantity, ensuring that the intervention altered only meal timing rather than caloric intake [23]. Beforehand, participants received thorough education on the principles of TRE 12:12, its potential health benefits, and adherence strategies in a 45-minute face-to-face session. Daily adherence was tracked through a WhatsApp group in which participants reported their first and last meal times each day; the researchers actively offered support and answered protocol questions. After 30 days, posttest measurements were taken using procedures identical to baseline, followed by an evaluation questionnaire covering adherence, side effects, and participants' subjective perceptions of the intervention.

Data analysis

Descriptive statistics were reported as mean ± standard deviation (SD) for continuous variables and as frequencies and percentages for categorical variables. The Shapiro–Wilk normality test was conducted before inferential analysis to verify distributional assumptions. Since all variables were normally distributed, paired-samples t-test was used to compare the pre- and post-intervention means. Given the non-controlled design, effect sizes were computed with Cohen's d to quantify the magnitude of change and effect sizes were interpreted using conventional thresholds: $|d| = 0.20$ (small), $|d| = 0.50$ (moderate), and $|d| \geq 0.80$ (large) [24]. Adherence was calculated as the percentage of days a participant successfully followed the TRE 12:12 protocol out of the 30 intervention days. Adherence and questionnaire results were summarized descriptively to illustrate the feasibility and acceptability of the intervention among working adults. Data were analyzed in IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA).

Results

Respondents' characteristics

The study included 21 adult workers who completed the 30-day TRE 12:12 intervention and their demographic characteristics are presented in **Table 1**. Mean age was 33.76±9.13 years with a balanced sex distribution; 10 men (47.6%) and 11 women (52.4%). Based on WHO Asia-Pacific BMI criteria, participants were classified as underweight (4.8%), normal weight (28.6%), overweight (33.3%), obesity class I (28.6%), and obesity class II (4.8%). Physical activity levels were generally low: 42.9% rarely exercised, 38.1% exercised 1–2 times per week, and 85.7% reported light-intensity activity (**Table 1**).

Table 1. Characteristics and physical activity profile of participants included in the study

Characteristics	Frequency (%)
Age (years), mean±SD	33.76±9.13
Sex	

Characteristics	Frequency (%)
Male	10 (47.6)
Female	11 (52.4)
Height (cm), mean±SD	162.29±7.43
Baseline Body Mass Index (BMI) category	
Underweight (<18.5 kg/m²)	1 (4.8)
Normal (18.5–22.9 kg/m²)	6 (28.6)
Overweight (23.0–27.4 kg/m²)	7 (33.3)
Obesity Class I (27.5–34.9 kg/m²)	6 (28.6)
Obesity Class II (≥ 35.0 kg/m²)	1 (4.8)
Exercise frequency (per week)	
≥6 times	1 (4.8)
3–5 times	3 (14.3)
1–2 times	8 (38.1)
Rarely/never	9 (42.9)
Physical activity intensity	
Vigorous	3 (14.3)
Light	18 (85.7)

Effect of time-restricted eating (TRE) on body weight and body composition

The changes in body weight and body composition after the 30-day 12:12 time-restricted eating intervention are summarized in **Table 2**. Significant reductions were observed in body weight (mean change: −2.38±1.97 kg; 95%CI: −3.28 to −1.48; p<0.001; Cohen's d=−1.206), BMI (−0.90±0.70 kg/m²; 95%CI: −1.21 to −0.58; p<0.001; d=−1.287), body fat percentage (−1.08±1.23%; 95%CI: −1.64 to −0.52; p=0.001; d=−0.876), visceral fat level (−1.12±0.72; 95%CI: −1.45 to −0.79; p<0.001; d=−1.548), and waist circumference (−5.82±3.37 cm; 95%CI: −7.36 to −4.29; p<0.001; d=−1.730). Skeletal muscle mass percentage increased modestly (0.36±0.55%; 95%CI: 0.11–0.61; p=0.008; d=0.646) (**Table 2**).

Table 2. Changes in body weight and body composition before and after the 12:12 time-restricted eating (TRE 12:12) intervention (n=21)

Variable	Pre-test	Post-test	Δ Mean±SD (95%CI)	p-value[a]	Cohen's d (effect size)[b]
	Mean±SD	Mean±SD			
Body weight (kg)	68.79±17.90	66.41±17.72	−2.38±1.97 (−3.28; −1.48)	<0.001*	−1.206
BMI (kg/m²)	25.79±4.85	24.89±4.88	−0.90±0.70 (−1.21; −0.58)	<0.001*	−1.287
Body fat (%)	29.48±5.33	28.40±5.18	−1.08±1.23 (−1.64; −0.52)	0.001*	−0.876
Visceral fat (level)	9.69±6.84	8.57±6.65	−1.12±0.72 (−1.45; −0.79)	<0.001*	−1.548
Skeletal muscle mass (%)[c]	27.58±3.18	27.94±3.14	+0.36±0.55 (0.11; 0.61)	0.008*	+0.646
Waist circumference (cm)	90.95±14.86	85.13±14.17	−5.82±3.37 (−7.36; −4.29)	<0.001*	−1.730

Δ: difference between post-test and pre-test; BMI: body mass index; CI: confidence interval
[a] Analyzed using paired samples t-test
[b] Cohen's d: <0.5=small; 0.5–0.8=moderate; >0.8=large
[c] Skeletal muscle mass change (+0.36%) falls within the established measurement-error margin of BIA devices for muscle estimation (±0.5–1.0%)
* Statistically significant at p<0.01

Adherence rate and intervention feasibility

Adherence to the 30-day 12:12 time-restricted eating protocol is presented in **Table 3**. Overall adherence was high, with participants completing a mean of 29.43 of 30 target days (98.1%). Fifteen participants (71.4%) completed the intervention without interruption, while six (28.6%) missed one to three days.

Table 3. Distribution of adherence to the 12:12 time-restricted eating (TRE 12:12) intervention

Adherence level (days)	Frequency (%)
Full adherence — 30 days	15 (71.4)
Incomplete adherence	
27 days	2 (9.5)

Adherence level (days)	Frequency (%)
28 days	3 (14.3)
29 days	1 (4.8)

Participants' perceptions of the intervention

Participants' perceptions of the TRE 12:12 intervention are presented in **Table 4**. Reported side effects were generally mild, most commonly hunger and fatigue (23.8% each), while 28.6% reported no side effects. Subjective energy levels were mostly favorable, with 66.7% reporting good and 9.5% reporting very good energy. Sleep quality was unchanged in most participants (61.9%) and improved in 33.3%, while eating quality was unchanged in 52.4% and improved in 38.1%. Within the eating window, 57.1% reported consuming one main meal per day. Perceived stress remained unchanged in 61.9% and decreased in 38.1%, with no participant reporting increased stress. Overall, most participants perceived the intervention as beneficial (85.7%) or slightly beneficial (9.5%), while only one participant (4.8%) considered it not beneficial.

Table 4. Participants' perceptions of the intervention

Category	Frequency (%)
Side effects/challenges	
None	6 (28.6)
Hunger	5 (23.8)
Fatigue	5 (23.8)
Constipation	3 (14.3)
Sleep disturbances	2 (9.5)
Subjective energy level during the intervention	
Very good	2 (9.5)
Good	14 (66.7)
Poor	4 (19.0)
Very poor	1 (4.8)
Sleep quality during the intervention	
Improved	7 (33.3)
No change	13 (61.9)
Worse	1 (4.8)
Eating quality during the intervention	
Healthier eating	8 (38.1)
No change	11 (52.4)
Uncontrolled eating	2 (9.5)
Main meals per day within the eating window	
One main meal	12 (57.1)
Two main meals	5 (23.8)
No fixed pattern	4 (19.0)
Perceived stress during the intervention	
Lower	8 (38.1)
Unchanged	13 (61.9)
Higher	0 (0.0)
Perceived benefits of the intervention	
Beneficial	18 (85.7)
Slightly beneficial	2 (9.5)
Not beneficial	1 (4.8)

Discussion

This study found that a 30-day TRE 12:12 intervention was associated with significant reductions in body weight, BMI, body fat percentage, visceral fat level, and waist circumference among adult workers. The mean body-weight reduction of 2.38 kg was slightly greater than the reduction reported in a recent meta-analysis of TRE interventions, although the small sample size and absence of a control group in the present study should be considered when interpreting this comparison [13,16]. These findings suggest that even a relatively mild TRE protocol, without prescribed calorie restriction, may support short-term weight and adiposity reduction in a workplace setting. The observed changes are biologically plausible because TRE may extend the daily fasting period sufficiently to promote intermittent metabolic switching, fat oxidation, circadian alignment, and autophagy-related processes [25-29]. However, these mechanisms were not directly measured in this study and should therefore be interpreted only as contextual explanations.

The reduction in visceral fat level and waist circumference is an important finding because visceral adiposity is more closely related to cardiometabolic risk than body weight alone [30]. Excess visceral fat is metabolically active and contributes to insulin resistance, dyslipidemia, inflammation, hypertension, and cardiovascular risk through endocrine and inflammatory pathways [30-32]. Previous studies have also shown that visceral adiposity indices are associated with future cardiovascular disease risk and atherosclerosis-related outcomes [33]. Therefore, the reduction in visceral fat observed in this study may have potential occupational-health relevance, particularly for workers with sedentary activity patterns. Nevertheless, this study did not assess cardiometabolic biomarkers, so the clinical implications of the observed body-composition changes require confirmation in future studies.

Skeletal muscle mass percentage increased slightly after the intervention, but the absolute change was small and within the known measurement-error range of BIA devices [34]. Thus, the result is better interpreted as preservation of skeletal muscle mass rather than true muscle gain. This distinction is important because weight-loss interventions may reduce lean body mass, especially when based on calorie restriction alone [35]. The preservation of muscle mass during TRE may be advantageous, but meaningful muscle gain would require structured resistance training and adequate protein intake [36]. Previous literature suggests that intermittent fasting may help preserve muscle when combined with sufficient dietary protein and appropriate physical activity, although the evidence remains context-dependent [27,37].

Adherence to the TRE 12:12 protocol was high, with an overall adherence rate of 98.1%, and most participants perceived the intervention as beneficial. Reported side effects, including hunger, fatigue, constipation, and sleep disturbances, were mild and did not lead to discontinuation. This supports the feasibility of TRE 12:12 as a workplace health-promotion strategy, particularly because the protocol modifies meal timing without requiring calorie counting or major dietary restriction [13,15,38]. The finding that most participants reported good or very good energy also suggests that the intervention did not substantially impair subjective daily functioning during the 30-day period [23]. From an occupational-health perspective, a simple and low-cost intervention such as TRE 12:12 may be easier to integrate into workplace wellness programs than more intensive dietary programs, especially when supported by education and simple digital monitoring [39].

These findings may have practical implications for obesity and cardiometabolic-risk prevention among workers. Obesity is associated with increased risk of noncommunicable diseases and productivity loss, including absenteeism and presenteeism [3,9]. Therefore, workplace-based lifestyle interventions that are feasible, acceptable, and inexpensive may contribute to both health promotion and workforce productivity. However, because this study was short-term and uncontrolled, TRE 12:12 should be considered a promising strategy rather than a definitive intervention. Its implementation should be accompanied by health education, monitoring of adherence and adverse effects, and encouragement of balanced nutrition and physical activity [12,39].

This study has some limitations. First, the one-group pretest–posttest design without a control group limits causal inference, because history, maturation, testing effects, and regression to the mean cannot be fully excluded [17]. Although the effect sizes were moderate to large, effect size estimates in small uncontrolled studies should be interpreted cautiously [24]. Second, physical activity, sleep quality, and stress were collected descriptively and were not included as covariates in multivariable analyses [40]. Third, the 30-day intervention period was too short to determine long-term sustainability, and the sample was small and recruited from a single workplace clinic, limiting generalizability [16]. Fourth, BIA is practical for field assessment but less precise than reference methods such as DXA or MRI, particularly for detecting small changes in skeletal muscle mass [21]. Finally, participants represented mixed baseline BMI categories, which reflects the real workplace population but introduces heterogeneity in baseline adiposity. Future studies should use randomized controlled designs with larger samples, longer follow-up, and appropriate comparison groups, such as habitual diet or conventional calorie restriction. Further research should also include objective dietary intake, physical activity, sleep, and stress measurements, as well as cardiometabolic biomarkers such as lipid profiles, fasting glucose, HbA1c, fasting insulin, HOMA-IR, hs-CRP, IL-6, adiponectin, and leptin. More precise body-composition methods and mechanistic biomarkers, including autophagy-related and oxidative-stress markers, would also help clarify whether the observed changes are directly attributable to TRE 12:12.

Conclusion

This study found that a 30-day TRE 12:12 intervention was associated with significant reductions in body weight, BMI, body fat percentage, visceral fat level, and waist circumference among adult workers. Skeletal muscle mass was generally preserved, suggesting that short-term weight reduction occurred without meaningful loss of muscle mass. The intervention also showed high adherence, mild reported side effects, and favorable participant perceptions, indicating that TRE 12:12 may be feasible and acceptable for workplace health-promotion programs. However, because this study used a one-group pretest–posttest design with a small sample and short intervention period, the findings should be interpreted as preliminary. Further randomized controlled studies with larger samples, longer follow-up, and more precise body-composition and cardiometabolic assessments are needed to confirm the effectiveness and sustainability of TRE 12:12 in working populations.

Ethics approval

Ethical approval for this study was obtained from the Health Research Ethics Committee of the Faculty of Public Health Universitas Indonesia (Ket-361/UN2.F10.ETK/PPM.00.02/2025). All participants provided written informed consent after receiving full explanations of the study's objectives, procedures, benefits, risks, and their right to withdraw at any time without consequence. Personal data confidentiality was protected through numerical identification codes, and all data were stored in an encrypted system accessible only to the research team, in line with the ethical principles of the Declaration of Helsinki.

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Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

Declaration of artificial intelligence use

AI-based language tools, including ChatGPT, Gemini, and DeepL, were used to improve grammar, sentence structure, and readability of the manuscript during the translation process. We confirm that all AI-assisted processes were critically reviewed by the authors to ensure the integrity and reliability of the results. The final decisions and interpretations presented in this article were solely made by the authors.

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