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Effect of Time-Restricted Eating on Weight Loss in Adults With Type 2 Diabetes
A Randomized Clinical Trial

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Abstract

IMPORTANCE Time-restricted eating (TRE) has become increasingly popular, yet longer-term randomized clinical trials have not evaluated its efficacy and safety in patients with type 2 diabetes (T2D).

OBJECTIVE To determine whether TRE is more effective for weight reduction and glycemic control than daily calorie restriction (CR) or a control condition in adults with T2D.

DESIGN, SETTING, AND PARTICIPANTS This 6-month, parallel-group, randomized clinical trial was performed between January 25, 2022, and April 1, 2023, at the University of Illinois Chicago. Participants were aged 18 to 80 years with obesity and T2D. Data analysis was based on intention to treat.

INTERVENTIONS Participants were randomized to 1 of 3 groups: 8-hour TRE (eating 12 to 8 PM only, without calorie counting), CR (25% energy restriction daily), or control.

MAIN OUTCOMES AND MEASURES The primary outcome measure was change in body weight by month 6. Secondary outcomes included changes in hemoglobin A_{1c} (HbA_{1c}) levels and metabolic risk factors.

RESULTS Seventy-five participants were enrolled with a mean (SD) age of 55 (12) years. The mean (SD) body mass index (calculated as weight in kilograms divided by height in meters squared) was 39 (7) and the mean (SD) HbA_{1c} level was 8.1% (1.6%). A total of 53 participants (71%) were women. One participant (1%) was Asian, 30 (40%) were Hispanic White, 40 (53%) were non-Hispanic Black, and 4 (5%) were non-Hispanic White. Participants in the TRE group were adherent with their eating window on a mean (SD) of 6.1 (0.8) days per week, and 17 (68%) in the CR group were adherent with their prescribed calorie goals over 6 months. The mean (SD) reduction in energy intake was −313 (509) kcal/d for TRE, −197 (426) kcal/d for CR, and −16 (439) kcal/d for controls. By month 6, body weight decreased significantly in the TRE group (−3.56% [95% CI, −5.92% to −1.20%]; $P = .004$) but not the CR group (−1.78% [95% CI, −3.67% to 0.11%]; $P = .06$), relative to controls. Levels of HbA_{1c} decreased in the TRE (−0.91% [95% CI, −1.61% to −0.20%]) and CR (−0.94% [95% CI, −1.59% to −0.30%]) groups, relative to controls, with no differences between the TRE and CR groups. Time in euglycemic range, medication effect score, blood pressure, and plasma lipid levels did not differ among groups. No serious adverse events were reported.

CONCLUSIONS AND RELEVANCE This randomized clinical trial found that a TRE diet strategy without calorie counting was effective for weight loss and lowering of HbA_{1c} levels compared with

(continued)

Key Points

Question Is time-restricted eating (TRE) without calorie counting more effective for weight loss and lowering of hemoglobin A_{1c} (HbA_{1c}) levels compared with daily calorie restriction (CR) in adults with type 2 diabetes (T2D)?

Findings In a 6-month randomized clinical trial involving 75 adults with T2D, TRE was more effective for weight loss (−3.6%) than CR (−1.8%) compared with controls. However, changes in HbA_{1c} levels did not differ between the TRE (−0.91%) and CR (−0.94%) groups compared with controls.

Meaning These findings suggest that time-restricted eating may be an effective alternative strategy to CR for lowering body weight and HbA_{1c} levels in T2D.

+ Visual Abstract

+ Supplemental content

Author affiliations and article information are listed at the end of this article.

Abstract (continued)

daily calorie counting in a sample of adults with T2D. These findings will need to be confirmed by larger RCTs with longer follow-up.

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Introduction

Approximately 1 in 10 US residents have type 2 diabetes (T2D).[1] If current trends continue, 1 in 3 US adults will have T2D by 2050.[1] Innovative lifestyle strategies to treat T2D are critically needed. Calorie restriction (CR) is generally encouraged as the first line of therapy to help people with T2D achieve their weight management goals and glycemic targets.[2] However, many patients find it difficult to adhere to CR because calorie intake must be vigilantly monitored every day. Another approach that limits the timing of food intake instead of the number of calories consumed has recently been popularized. This diet is termed *time-restricted eating* (TRE) and involves confining daily food intake to 6 to 10 hours and fasting for the remaining hours. Evidence shows that limiting the eating window to 6 to 10 hours within a 24-hour period naturally reduces energy intake by 200 to 500 kcal/d.[3-5] Moreover, since TRE allows individuals to self-select foods and eat freely during a large part of the day, adherence remains high for up to 12 months.[6] Therefore, TRE may be an attractive alternative to CR for weight loss in patients with T2D.

Only 2 TRE trials[7,8] to date have been conducted in adults with T2D. The preliminary findings of these trials show that TRE reduced body weight by 1% to 4%, lowered hemoglobin A_{1c} (HbA_{1c}) levels by 1.5%, and increased time spent in the euglycemic range compared with controls.[7,8] However, these trials were limited by short duration (3-12 weeks) and lack of comparison with standard care (ie, daily CR).

Accordingly, we conducted a 6-month, randomized clinical trial comparing the effects of 8-hour TRE (eating all food between 12:00 PM and 8:00 PM, without calorie counting) with CR (25% restriction daily) and a control condition on body weight and glycemic control in a group of adults with T2D and obesity. We hypothesized that the TRE group would achieve greater weight loss and larger reductions in HbA_{1c} levels, compared with a CR group and a control group.

Methods

The protocol for this randomized clinical trial was approved by the Office for the Protection of Research Subjects at the University of Illinois Chicago, and written informed consent was obtained from all participants. The full trial protocol and statistical analysis plan are provided in Supplement 1. This study followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guidelines.

Trial Participants

The trial was a 6-month, single-center, randomized clinical trial conducted at the University of Illinois Chicago between January 25, 2022, and April 1, 2023 (eFigure 1 in Supplement 2). Inclusion criteria were as follows: previous diagnosis of T2D, HbA_{1c} levels between 6.5% and 11.0% (to convert to proportion of total hemoglobin, multiply by 0.01), 18 to 80 years of age, and body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) between 30 and 50. Exclusion criteria consisted of unstable weight for 3 months prior to the beginning of the study (>4% weight loss or gain), history of eating disorders, eating within less than a 10-hour window at baseline, nightshift work, pregnant or trying to become pregnant, and current smoking. Self-reported race and

ethnicity data (including Asian, Hispanic White, non-Hispanic Black, and non-Hispanic White) were collected given that Hispanic and non-Hispanic Black adults have a high prevalence of T2D in the US.

Randomization and Blinding

Participants were randomized in a 1:1:1 ratio to a TRE, CR, or control group. Randomization was performed by a stratified random sampling procedure by sex, age (18-49 and 50-80 years), BMI (30-39 and 40-50), and HbA_{1c} level (6.50%-8.75% and 8.76%-11.00%). Participants were not blinded.

Intervention Groups

Participants in the TRE group ate ad libitum between 12:00 and 8:00 PM daily and fasted from 8:00 PM to 12:00 PM the following day. During the 8-hour eating window, participants were not required to monitor caloric intake, and there were no restrictions on types or quantities of food consumed. During the 16-hour fasting window, participants were encouraged to drink plenty of water and were permitted to consume energy-free drinks. Participants self-monitored adherence to the eating window using a log in which they recorded the times that they started and stopped eating each day.

Participants in the CR group were instructed to reduce their energy intake by 25% of their baseline energy needs every day. Total energy expenditure was calculated using the Mifflin equation.[9] Participants met with a study dietitian (V.P.) at the beginning of the trial to develop individualized weight loss meal plans and self-monitored adherence to their calorie target by logging food intake into an app every day.

Control participants were instructed to maintain their weight and usual eating and exercise habits. Control participants visited the research center at the same frequency as the intervention participants to provide outcome measurements.

Participants in the TRE, CR, and control groups met with the study dietitian weekly from baseline to month 3 (by telephone or Zoom) and then biweekly thereafter. Body weight, adherence, medication changes, and adverse events were recorded during these calls. Participants in the TRE and CR groups were also taught how to make general healthy food choices that conform to American Diabetes Association nutrition guidelines.[2] All participants were instructed not to change their physical activity habits throughout the trial.

Medication Management

The medication management protocol was developed based on the literature.[10,11] If the participant's baseline HbA_{1c} level was below 7.0%, sulfonylureas were discontinued, the dose of short-acting insulin was reduced by 50%, and the dose of long-acting remained unchanged. If the participant's baseline HbA_{1c} level was greater than 7.0% but below 8.5%, the dose of sulfonylureas was reduced by 50%, the dose of short-acting insulin was reduced by 10%, and the dose of long-acting insulin remained unchanged. If the participant's baseline HbA_{1c} level was greater than 8.5%, doses of sulfonylurea, short-acting insulin, and long-acting insulin remained unchanged. No medication adjustments were made for controls.

Blood Glucose Level Monitoring

All participants wore a continuous glucose monitor (CGM [Dexcom G7; DexCom, Inc]) for 10 days at baseline, month 3, and month 6. The CGM data were used to detect hypoglycemic (glucose level <70 mg/dL [to convert to mmol/L, multiply by 0.0555]) or hyperglycemic (glucose level >180 mg/dL) events. When participants were not wearing the CGM, they tested their blood glucose levels daily using a lancing device and glucose monitor.

Outcome Measures

The primary outcome of the study was percentage change in body weight among the TRE, CR, and control groups by month 6. Secondary outcomes included changes in HbA_{1c} levels, time in

euglycemic range (glucose levels 70-180 mg/dL), mean glucose level (measured by CGM), medication effect score,[12] body composition (measured by dual-energy x-ray absorptiometry), blood pressure and heart rate, plasma lipid levels, dietary intake (measured by the ASA-24 [automated self-administered 24-hour] dietary assessment tool[13]), dietary adherence, physical activity (steps per day), and weekly adverse events among the TRE, CR, and control groups by month 6. Analytical methods are detailed in Supplement 1. Reporting of serious adverse events followed requirements mandated by the University of Illinois Office for Protection of Research Subjects (Supplement 1).

Statistical Analysis

For the sample size calculation, we estimated that TRE and CR groups would reduce body weight by 7% and 3%, respectively, by month 6 compared with controls (estimated no change in body weight). We calculated that 21 participants per group would provide 80% power to detect a significant difference in body weight among the TRE, CR, and control groups by month 6, using an overall *F* test from a 1-way analysis of variance with $\alpha = .05$, effect size of 0.4096, and a common SD of 7%. We anticipated a dropout rate of 15%.[4] Thus, we aimed to recruit 75 participants (25 per group), assuming that 63 participants (21 per group) would complete the trial.

Data are shown as mean (95% CI) unless otherwise noted. A Bonferroni-adjusted 2-tailed $P < .017$ was considered statistically significant for pairwise group comparisons of percentage change in body weight. *P* values generated from analyses of secondary outcomes were not adjusted for multiplicity and are considered descriptive. We conducted an intention-to-treat analysis, which included data from all 75 participants who underwent randomization. Results are reported by intention-to-treat analysis unless indicated otherwise.

A linear mixed model was used to assess time, group, and time × group effects for each outcome. In each model, time and group effects (and their interaction) were estimated without imposing a linear time trend. In models for body weight, which was measured at 7 time points (baseline and each of 6 months of follow-up), time was modeled with cubic splines. In models of all other outcome variables, which were measured at 2 time points (baseline and month 6), time was modeled as a categorical variable. All models were adjusted for baseline use of sodium-glucose transport protein 2 inhibitors and glucagon-like peptide-1 receptor agonists to account for empirical baseline differences in medication use between treatment groups.

For each outcome variable, linear modeling assumptions were assessed with residual diagnostics. To account for the potential of nonuniform variances (heteroskedasticity) between treatment groups due to random chance, all CIs and *P* values from linear mixed models were calculated using robust variance estimators (sandwich estimators).[14-16] Intraclass correlation coefficients from each linear mixed effect were also calculated. To assess the effect of loss to follow-up on study findings, we conducted a sensitivity analysis using multiple imputation. Multiple imputation can incorporate observed data not otherwise accounted for in the model (eg, using baseline insulin levels to impute missing time in euglycemic range) to estimate multiple values for each missing data point and account for sampling variability. Missing follow-up data were imputed under the assumption that systematic differences between missing and observed outcomes can be explained by baseline values of the outcome as well as baseline values of height and waist circumference (and medication effect score and HbA_{1c} level for glycemic outcomes), and all previous time points of weight. All analyses were performed using R software, version 4.3.1 (R Project for Statistical Computing).

Results

Trial Participants

We screened 127 people and enrolled 75 participants (**Figure 1**). Participants had a mean (SD) age of 55 (12) years, mean (SD) BMI of 39 (7), and mean (SD) HbA_{1c} level of 8.1% (1.6%). Fifty-three participants (71%) were women and 22 (29%) were men. One participant (1%) was Asian, 30 (40%) were Hispanic White, 40 (53%) were non-Hispanic Black, and 4 (5%) were non-Hispanic White

(**Table 1**). The attrition rate (ie, participants lost to follow-up) was 2 (8%) in the TRE group, 3 (12%) in the CR group, and 1 (4%) in the control group. The reasons for participant attrition included personal reasons, inability to contact, not wanting to be in the control group, and motor vehicle crash.

Weight Loss and Body Composition

By month 6, mean body weight significantly decreased in the TRE group (−3.56% [95% CI, −5.92% to −1.20%]; *P* = .004) but not the CR group (−1.78% [95% CI, −3.67% to 0.11%]; *P* = .06), relative to controls (**Figure 2**A and **Table 2**). Fat mass decreased in the TRE group by month 6 (−2.49 [95% CI, −4.41 to −0.58] kg) but not the CR group (−1.65 [95% CI, −3.33 to 0.04] kg), relative to controls (Table 2). Both TRE and CR led to reductions in waist circumference by month 6, but not lean mass or visceral fat mass, compared with controls. Relative to controls, BMI decreased in the TRE group by month 6, but not the CR group.

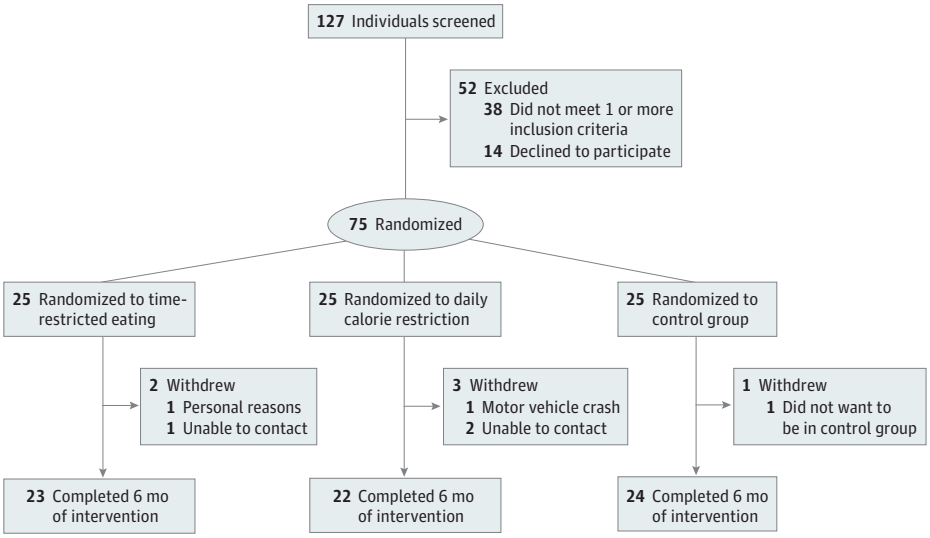
Glycemic Control and Medication Effect Score

By month 6, mean HbA_{1c} levels were reduced in the TRE group (−0.91% [95% CI, −1.61% to −0.20%]) and CR group (−0.94% [95% CI, −1.59% to −0.30%]), relative to controls, with no differences between the TRE and CR group (0.04% [95% CI, −0.64% to 0.72%]) (Figure 2B and Table 2). Mean glucose levels decreased in the TRE group (−42.53 [95% CI, −79.73 to −5.33] mg/dL) and CR group (−48.55 [95% CI, −85.55 to −11.54] mg/dL), relative to controls, with no differences between the TRE and CR groups (6.02 [95% CI, −12.67 to 24.70] mg/dL) (Figure 2C and Table 2). Time in the euglycemic range and medication effect scores were not associated with treatment group in any pairwise comparisons at month 6 (Table 2). Medication use at baseline and month 6 is reported in eTable 1 in Supplement 2.

Sensitivity Analysis Using Multiple Imputation

Conclusions for body weight and HbA_{1c} level did not change from the primary analyses to the sensitivity analyses (eTable 2 in Supplement 2), demonstrating that the results are robust to misspecification of the missingness mechanism. However, sensitivity analyses differed from primary analyses for some secondary outcomes: fat mass decreased in both the TRE and the CR groups by month 6 relative to controls (rather than in the TRE group alone), and mean glucose levels decreased in the CR group only. Conclusions did not change between the primary analysis and sensitivity analysis for any other secondary outcome.

Figure 1. Study Flowchart



Plasma Lipid Levels and Blood Pressure

Changes in blood pressure, heart rate, total cholesterol, LDL cholesterol, HDL cholesterol, and triglyceride concentrations were observed. However, these changes were not associated with treatment group in any pairwise comparisons at month 6 (Table 2).

Table 1. Baseline Characteristics of the Study Participants[a]

Characteristic	Participant group				Study completion	
	TRE (n = 25)	CR (n = 25)	Control (n = 25)	All (N = 75)	Completed (n = 69)	Dropped out (n = 6)
Age, y	56 (13)	55 (13)	54 (11)	55 (12)	56 (12)	46 (10)
Sex, No. (%)						
Women	18 (72)	17 (68)	18 (72)	53 (71)	51 (74)	2 (33)
Men	7 (28)	8 (32)	7 (28)	22 (29)	18 (26)	4 (67)
Race and ethnicity, No. (%)						
Asian	0	1 (4)	0	1 (1)	0	1 (17)
Hispanic White	10 (40)	9 (36)	11 (44)	30 (40)	27 (39)	3 (50)
Non-Hispanic Black	12 (48)	14 (56)	14 (56)	40 (53)	38 (55)	2 (33)
Non-Hispanic White	3 (12)	1 (4)	0	4 (5)	4 (6)	0
T2D duration, y	15 (11)	14 (9)	12 (9)	14 (9)	14 (9)	5 (4)
Diabetes medications, No. (%)						
Oral hypoglycemic agents						
Metformin	21 (84)	19 (76)	21 (84)	61 (81)	57 (83)	4 (67)
DPP-4 inhibitors	0	4 (16)	1 (4)	5 (7)	5 (7)	0
SGLT-2 inhibitors	9 (36)	1 (4)	5 (20)	15 (20)	14 (20)	1 (17)
GLP-1 receptor agonists	8 (32)	5 (20)	6 (24)	19 (25)	18 (26)	1 (17)
Sulfonylureas	2 (8)	7 (28)	2 (8)	11 (15)	9 (13)	2 (33)
Insulin	13 (52)	4 (16)	9 (36)	26 (35)	25 (36)	1 (17)
Medication effect score[b]						
Oral hypoglycemic agents	1.3 (0.7)	1.0 (0.8)	1.3 (0.9)	1.2 (0.8)	1.2 (0.8)	1.2 (1.1)
Insulin	0.5 (0.7)	0.2 (0.5)	0.3 (0.6)	0.4 (0.6)	0.4 (0.6)	0.2 (0.6)
Body weight, kg	105 (25)	104 (17)	107 (22)	105 (21)	105 (22)	108 (16)
Height, cm	165 (7)	166 (10)	165 (8)	165 (8)	165 (8)	171 (10)
BMI	39 (9)	38 (5)	39 (7)	39 (7)	39 (7)	37 (4)
HbA_{1c} level, %	8.3 (2.0)	8.1 (1.5)	7.9 (1.3)	8.1 (1.6)	8.0 (1.6)	8.6 (1.7)
Time in euglycemic range, %	63 (30)	60 (30)	62 (32)	62 (30)	64 (30)	37 (15)
Glucose level, mg/dL	180 (47)	183 (59)	177 (58)	180 (54)	178 (56)	203 (20)
Body composition						
Fat mass, kg	43 (10)	49 (10)	47 (14)	46 (11)	46 (12)	46 (9)
Lean mass, kg	54 (13)	52 (10)	53 (10)	53 (11)	52 (9)	56 (20)
Visceral fat mass, kg	1.9 (0.7)	2.5 (1.0)	2.2 (0.9)	2.2 (0.9)	2.2 (0.9)	2.4 (1.3)
Waist circumference, cm	117 (13)	120 (9)	121 (15)	120 (13)	120 (13)	118 (10)
Blood pressure, mm Hg						
SBP	135 (17)	137 (17)	131 (20)	134 (18)	134 (18)	135 (19)
DBP	85 (12)	87 (13)	85 (9)	86 (11)	85 (11)	90 (15)
Heart rate, bpm	78 (14)	79 (13)	80 (12)	79 (13)	78 (13)	85 (14)
Plasma lipid levels, mg/dL						
Total cholesterol	164 (44)	171 (43)	163 (39)	166 (42)	165 (43)	174 (27)
LDL cholesterol	90 (37)	92 (36)	94 (37)	92 (36)	92 (37)	94 (24)
HDL cholesterol	48 (12)	48 (14)	47 (9)	48 (12)	48 (12)	42 (6)
Triglycerides	130 (58)	144 (64)	121 (37)	132 (55)	127 (50)	189 (75)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); bpm, beats per minute; CR, calorie restriction; DBP, diastolic blood pressure; DPP-4, dipeptidyl peptidase 4; GLP-1, glucagonlike peptide-1; HbA_{1c}, hemoglobin A_{1c}; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SBP, systolic blood pressure; SGLT-2, sodium-glucose transport protein 2; T2D, type 2 diabetes; TRE, time-restricted eating.

SI conversion factors: To convert cholesterol to mmol/L, multiply by 0.0258; glucose to mmol/L, multiply by 0.0555; HbA_{1c} to proportion of total hemoglobin, multiply by 0.01; triglycerides to mmol/L, multiply by 0.0113.

[a] Unless otherwise indicated, data are expressed as mean (SD).

[b] Calculated as (actual drug dose/maximum drug dose) × drug mean adjustment factor. A higher score corresponded to a higher dose of diabetes medication, and a reduction corresponded to a reduction in diabetes medication.

Adherence and Energy Intake

The mean (SD) caloric deficit was −313 (509) kcal/d for the TRE group, −197 (426) kcal/d for the CR group, and −16 (439) kcal/d for the control group over 6 months. Differences in dietary intake among groups are given in **Table 3**. The TRE group reported being adherent with their eating window a mean (SD) of 6.1 (0.8) days per week (87% of days) over 6 months (eFigure 2 in Supplement 2). In the CR group, 17 participants (68%) reported being adherent with their prescribed calorie goals during the 6-month trial (eFigure 2 in Supplement 2). Participants in the TRE group reported finding their diet intervention easier to adhere to compared with CR group participants (eFigure 3 in Supplement 2).

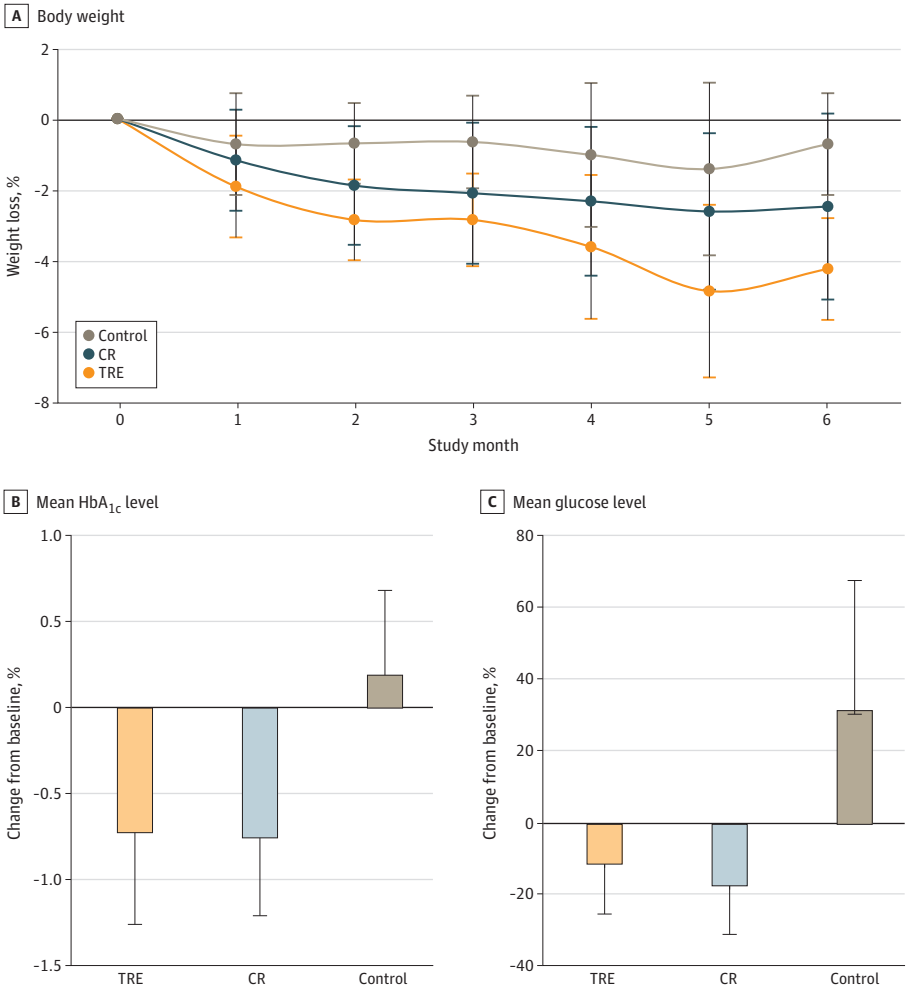
Daily Eating Window, Diet Quality, and Physical Activity

The daily eating window in the TRE group decreased from baseline to month 6 but remained unchanged in the CR and control groups (Table 3). Dietary intake and physical activity did not differ over time or between groups (Table 3).

Adverse Events

No serious adverse events were reported. Occurrences of hypoglycemia and hyperglycemia did not differ between groups (eTable 3 in Supplement 2).

Figure 2. Change in Body Composition and Glycemic Control in the Study Groups



Data were included for 75 participants; means were estimated using an intention-to-treat analysis using a linear mixed model. Error bars indicate 95% CIs for each parameter from baseline by diet group. CR indicates calorie restriction; TRE, time-restricted eating.

Table 2. Body Weight, Glycemic Control, and Cardiometabolic Risk Factors[a]

Variable	No. of participants		Participant group, mean change from baseline (95% CI)			Mean difference between groups (95% CI)		
	Baseline	6 mo	TRE	CR	Control	TRE vs CR	TRE vs control	CR vs control
Weight								
Body weight, % lost	75	68	−4.28 (−6.26 to −2.31)	−2.50 (−3.83 to −1.18)	−0.72 (−2.14 to 0.69)	−1.78 (−4.09 to 0.53)	−3.56 (−5.92 to −1.20)[b]	−1.78 (−3.67 to 0.11)
Body weight, kg	75	68	−4.52 (−6.73 to −2.30)	−2.63 (−3.99 to −1.27)	−1.07 (−2.70 to 0.57)	−1.89 (−4.42 to 0.64)	−3.45 (−6.13 to −0.77)[b]	−1.56 (−3.63 to 0.51)
Glycemic control								
HbA_{1c} level, %	72	66	−0.72 (−1.25 to −0.18)	−0.75 (−1.20 to −0.30)	0.19 (−0.30 to 0.68)	0.04 (−0.64 to 0.72)	−0.91 (−1.61 to −0.20)[c]	-0.94 (−1.59 to −0.30)[c]
Time in euglycemic range, %	67	56	4.78 (−3.52 to 13.08)	10.65 (2.65 to 18.65)	−7.81 (−24.90 to 9.27)	−5.87 (−17.03 to 5.28)	12.59 (−5.70 to 30.89)	18.46 (0.31 to 36.62)
Mean glucose level, mg/dL	67	56	−11.02 (−24.85 to 2.82)	−17.03 (−30.49 to −3.58)	31.51 (−4.54 to 67.56)	6.02 (−12.67 to 24.70)	−42.53 (−79.73 to −5.33)[c]	−48.55 (−85.55 to −11.54)[c]
Medication effect score								
OHA	75	69	−0.12 (−0.26 to 0.01)	0.04 (−0.15 to 0.23)	0.03 (−0.15 to 0.21)	−0.16 (−0.38 to 0.06)	−0.15 (−0.37 to 0.07)	0.01 (−0.25 to 0.26)
Insulin	75	69	−0.02 (−0.10 to 0.07)	−0.02 (−0.05 to 0.01)	0.00 (0.00 to 0.00)	0.01 (−0.08 to 0.09)	−0.02 (−0.10 to 0.07)	−0.02 (−0.05 to 0.01)
Body composition								
Fat mass, kg	71	65	−2.77 (−4.36 to −1.18)	−1.92 (−3.20 to −0.65)	−0.28 (−1.46 to 0.90)	−0.85 (−2.82 to 1.13)	−2.49 (−4.41 to −0.58)[c]	−1.65 (−3.33 to 0.04)
Lean mass, kg	71	65	−0.97 (−2.04 to 0.10)	−0.46 (−1.15 to 0.23)	−0.59 (−1.49 to 0.32)	−0.51 (−1.74 to 0.72)	−0.38 (−1.74 to 0.98)	0.13 (−0.98 to 1.23)
Visceral fat mass, kg	70	64	−0.16 (−0.36 to 0.05)	−0.18 (−0.32 to −0.04)	−0.07 (−0.18 to 0.04)	0.02 (−0.21 to 0.26)	−0.09 (−0.31 to 0.13)	−0.11 (−0.28 to 0.06)
Waist circumference, cm	74	67	−3.92 (−5.93 to −1.91)	−3.97 (−6.03 to −1.92)	−0.48 (−1.66 to 0.71)	0.05 (−2.74 to 2.84)	−3.44 (−5.71 to −1.18)[c]	−3.50 (−5.80 to −1.20)[c]
BMI	75	68	−1.78 (−2.63 to −0.94)	−0.89 (−1.36 to −0.41)	−0.37 (−0.95 to 0.22)	−0.90 (−1.83 to 0.04)	−1.41 (−2.41 to −0.42)[c]	−0.52 (−1.25 to 0.21)
Blood pressure, mm Hg								
SBP	75	65	−4.45 (−9.98 to 1.07)	−3.91 (−9.33 to 1.52)	1.52 (−4.45 to 7.49)	−0.55 (−8.05 to 6.96)	−5.98 (−13.87 to 1.92)	−5.43 (−13.25 to 2.39)
DBP	75	65	−2.88 (−6.92 to 1.16)	−1.47 (−3.86 to 0.93)	0.06 (−3.22 to 3.34)	−1.41 (−5.97 to 3.14)	−2.94 (−7.98 to 2.10)	−1.52 (−5.46 to 2.41)
Heart rate, bpm	75	65	−2.48 (−6.79 to 1.84)	−1.77 (−6.03 to 2.49)	−0.84 (−6.44, to 4.75)	−0.71 (−6.61 to 5.19)	−1.63 (−8.51 to 5.24)	−0.93 (−7.77 to 5.91)
Plasma lipid levels, mg/dL								
Total cholesterol	71	60	−0.18 (−10.55 to 10.20)	−8.12 (−22.86 to 6.63)	−1.88 (−15.67 to 11.90)	7.94 (−9.47 to 25.35)	1.71 (−14.97 to 18.38)	−6.23 (−25.76 to 13.30)
LDL cholesterol	71	60	−0.23 (−9.56 to 9.10)	−4.57 (−16.19 to 7.04)	−4.86 (−16.76 to 7.05)	4.34 (−10.04 to 18.73)	4.63 (−9.99 to 19.24)	0.28 (−15.81 to 16.38)
HDL cholesterol	71	60	3.20 (0.88 to 5.52)	−0.23 (−3.68 to 3.23)	1.02 (−1.57 to 3.62)	3.43 (−0.60 to 7.47)	2.18 (−1.19 to 5.54)	−1.25 (−5.44 to 2.93)
Triglycerides	71	60	−15.43 (−37.92 to 7.06)	−9.53 (−25.14 to 6.08)	3.70 (−13.32 to 20.73)	−5.90 (−32.3 to 20.59)	−19.13 (−46.42 to 8.16)	−13.23 (−35.62 to 9.15)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CR, calorie restriction; DBP, diastolic blood pressure; HbA_{1c}, hemoglobin A_{1c}; HDL, high-density lipoprotein; LDL, low-density lipoprotein; OHA, oral hypoglycemic agent; SBP, systolic blood pressure; TRE, time-restricted eating.

SI conversion factors: To convert cholesterol to mmol/L, multiply by 0.0258; glucose to mmol/L, multiply by 0.0555; HbA_{1c} to proportion of total hemoglobin, multiply by 0.01; triglycerides to mmol/L, multiply by 0.0113.

[a] Means were estimated using an intention-to-treat analysis using a linear mixed model with 95% CIs for each parameter from baseline by diet group.

[b] Indicates statistical significance using Bonferroni-adjusted 2-tailed $P < .017$.

[c] Indicates statistical significance using $P < .05$.

Discussion

Findings of this randomized clinical trial show that 8-hour TRE produced greater weight loss when compared with CR and a control condition. Despite the greater weight loss achieved by the TRE group, reductions in HbA_{1c} levels were similar in the TRE and CR groups compared with the control group. Participants in the TRE group found it easier to adhere to their intervention and achieved greater overall energy restriction compared with the CR group. Medication effect score did not change in any group, and no serious adverse events were reported.

Only 2 clinical trials[7,8] to date have examined how TRE affects body weight in patients with T2D. Che and colleagues[8] demonstrated that 12 weeks of 10-hour TRE (without calorie counting) reduced body weight by 3.5% compared with controls in 120 adults with obesity and T2D. Likewise, Andriessen et al[7] showed that 9-hour TRE produced 1.1% weight loss after 3 weeks compared with controls among 14 men and women with obesity and T2D. The weight loss produced by our 8-hour TRE intervention was slightly greater (4.3% from baseline) than that of previous reports,[7,8] but this was most likely due to the longer intervention period (6 months). In contrast, the weight loss by the CR group was not significant relative to the control or TRE group. This is surprising, as CR generally reduces body weight by 4% to 7% after 6 months in people with T2D.[17-19] However, the participants in the CR group in our trial reported more difficulty with adhering to their intervention, relative to TRE. Since CR is commonly prescribed as a first-line intervention in T2D, it is likely that our participants had already tried calorie counting in the past, without success. Time-restricted eating may have served as a refreshing alternative to CR, in that it only required patients to count time instead of calories, which may have bolstered overall adherence and weight loss in the TRE group.

Reductions in HbA_{1c} levels were similar for participants in the TRE (−0.91%) and CR (−0.94%) groups, relative to controls. Our findings for HbA_{1c} levels are comparable to other TRE trials in T2D[7,8] and the Look AHEAD (Action for Health in Diabetes) study, which implemented daily CR.[20] The improvements in HbA_{1c} levels by CR are somewhat unexpected, since only the TRE group lost weight relative to controls. However, both TRE and CR led to comparable reductions in waist circumference (a surrogate marker of visceral fat mass). Evidence suggests that visceral fat mass may be a stronger factor associated with changes in glycemic control than body weight alone.[21,22] Moreover, both the TRE and CR groups received individualized diabetes nutrition counseling, which has been shown

Table 3. Dietary Intake and Physical Activity

	Participant group, mean (SD)[a]					
	TRE		CR		Control	
Variable	Baseline	6 mo	Baseline	6 mo	Baseline	6 mo
Daily eating window	11 h 55 min (1 h 37 min)	8 h 3 min (1 h 54 min)[b]	10 h 29 min (1 h 36 min)	10 h 23 min (1 h 35 min)	10 h 23 min (1 h 26 min)	10 h 21 min (1 h 14 min)
Energy intake, kcal/d	1978 (582)	1665 (468)[b]	1707 (319)	1510 (358)[b]	1834 (354)	1818 (14)
Dietary intake						
Protein, %	18 (4)	19 (4)	17 (4)	17 (6)	19 (4)	19 (4)
Carbohydrates, %	42 (7)	41 (7)	41 (5)	42 (8)	41 (9)	40 (9)
Total sugar, %	15 (5)	14 (6)	15 (4)	15 (7)	15 (6)	14 (4)
Fat, %	40 (4)	40 (5)	42 (3)	41 (9)	40 (5)	41 (7)
Saturated fat, %	13 (2)	13 (3)	13 (2)	12 (3)	13 (2)	12 (2)
Cholesterol, mg	363 (146)	302 (97)	329 (149)	306 (111)	352 (126)	308 (142)
Fiber, g	16 (6)	15 (6)	15 (6)	14 (6)	15 (4)	13 (4)
Sodium, mg/d	3602 (1233)	3402 (790)	3259 (866)	2927 (614)	3311 (1095)	3126 (1291)
Caffeine, mg/d	91 (66)	93 (107)	90 (78)	81 (93)	89 (99)	96 (99)
Alcohol, g/d	2 (4)	1 (1)	2 (3)	1 (2)	0 (1)	0 (1)
Physical activity, steps/d	5568 (2908)	6049 (2625)	6142 (4885)	6025 (4701)	6051 (2623)	5512 (2545)

Abbreviations: CR, calorie restriction; TRE, time-restricted eating.

[a] Only observed values are included. A total of 20 of 25 participants in the TRE group, 20 of 25 in the CR group, and 19 of 25 in the control group returned all food recalls.

[b] Significantly different from baseline ($P < .05$).

significantly improve HbA_{1c} levels.[23,24] These factors may explain why similar improvements in HbA_{1c} levels were noted in the TRE and CR groups, even though only the TRE group lost weight relative to controls.

Our findings also show that TRE is safe in patients who are using either diet alone or medications to control their T2D. However, for people using sulfonylureas and/or insulin, adopting a TRE regimen will require medication changes and regular monitoring, particularly in the initial stages of the diet.

Hispanic and non-Hispanic Black adults are among the racial and ethnic groups with the highest prevalence of T2D in the US.[25] Our results show that TRE is effective for weight loss and HbA_{1c} level reductions in a sample population that was representative of these 2 groups. Time-restricted eating is an appealing approach to weight loss in that it can be adopted at no cost, allows patients to continue consuming familiar foods, and does not require complicated calorie counting. Since the literature on TRE is still quite limited,[26] our trial may help to improve the health of groups with a high prevalence of T2D by filling in these critical knowledge gaps.

Limitations

Our study has some limitations, which include the relatively short trial duration and the lack of blinding of participants. Moreover, a higher percentage of participants in the TRE group were using sodium-glucose transport protein 2 inhibitors and glucagonlike peptide-1 receptor agonists at baseline. These medications could have influenced our body weight findings,[27] even though participants had stable weight before enrollment. To control for these confounding variables, we accounted for the use of these medications in the analyses of our primary and secondary outcomes. In addition, we relied on self-reported dietary intake. Since individuals with obesity tend to underreport energy consumption by 15% to 20%,[28] it is likely that our estimates of energy intake are inaccurate. Last, TRE itself can be associated with greater self-monitoring and lower caloric intake, so although these effects were noted in the TRE group, these are expected as part of the intervention.

Conclusion

This randomized clinical trial found that 8-hour TRE without calorie counting was an effective alternative diet strategy for weight loss and lowering of HbA_{1c} levels compared with daily calorie counting in a sample of adults with T2D and obesity. These findings will need to be confirmed by larger RCTs with longer follow-up.

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SUPPLEMENT 1.
Trial Protocol

SUPPLEMENT 2.

eTable 1. Medication Use at Baseline and Month 6
eTable 2. Multiple Imputation Sensitivity Analysis Results
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SUPPLEMENT 3.

Data Sharing Statement