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Similar body composition outcomes following volumetric diet and time-restricted eating in middle-aged individuals: a 12-week randomized controlled trial

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Abstract

Introduction Overweight and obesity are increasing global challenges associated with severe health risks. Lifestyle factors like easy access to high-caloric foods and a decrease in physical activity contribute to weight gain. The increase in fat mass (FM) and decrease in lean body mass (LBM) are supported by age-related changes in body composition by the age of 30. Two dietary strategies, the volumetrics diet (VD) and time-restricted eating (TRE), have shown promise in achieving sustainable loss of body weight (BW) and FM without requiring food group exclusions or portion reductions. This study aimed to compare the impact of VD and TRE on body composition parameters and their adherence rate in middle-aged normal-weight to overweight physically active people over 12 weeks.

Methods In this randomized controlled trial, 37 physically active participants were allocated to either VD or TRE (VD: $n = 21$, age: 39.48 ± 8.83 years, body mass index (BMI): 25,38 ± 4.37 kg/m^2; TRE: $n = 16$, age: 42.06 ± 8.47, BMI: 26.38 ± 2.81 kg/m^2). Participants followed their assigned dietary strategy for 12 weeks while documenting their daily food intake using the FDDB app. Adherence to the diets was self-reported weekly. The VD group consumed meals with an energy density ≤ 1.5 kcal/g and the TRE group restricted calorie intake to an 8-hour window (11:30 AM–7:30 PM). Measurements of BW, FM, LBM, BMI, waist circumference (WC) and hip circumference (HC) were taken at baseline (T0) and after 4 (T1), 8 (T2) and 12 weeks (T3). Statistical analysis included linear mixed-effect models to compare time, group and interaction effects on body composition.

Results Both VD and TRE groups showed significant reductions in BW ($p = 0.0002$; d = 0.61), absolute FM ($p < 0.0001$; d = 0.85), relative FM ($p < 0.0001$; d = 0.84), BMI ($p = 0.0001$; d = 0.60), WC ($p < 0.0001$; d = 0.92), HC ($p = 0.003$; d = 0.51) and WHR ($p < 0.0001$; d = 0.90) after 12 weeks. No significant differences were observed between groups or in interaction effects for these parameters. Both groups maintained LBM throughout the intervention. Adherence rates were significantly higher in TRE (5.78 ± 1.13 days/week) compared to VD (5.29 ± 1.49 days/week; $p = 0.0002$). Adherence declined over time in both groups but not significantly. Dietary analysis showed no significant differences in energy and macronutrient intake.

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Conclusion VD led to the same results as TRE but with a significantly lower adherence rate in the 12-week intervention period. Both dietary approaches reduced BW and FM and maintained LBM in middle-aged, physically active individuals without changing physical activity levels. Therefore, VD and TRE may counteract age-related body composition changes as long-term measures. Further studies with larger samples and a longer study duration are needed to confirm these findings.

Registration number DRKS00033809.

Keywords Body composition, Time-restricted eating, Volumetrics diet, Overweight, Middle-aged person

Introduction

Overweight and obesity have been growing problems across the globe for the past decades [1–3]. With increasing body weight and a rise in fat mass, the risks for cardiovascular diseases, type 2 diabetes mellitus, and mental health disorders also increase [3]. The economic consequences, such as high costs for the healthcare system, should also not be neglected [4]. Lifestyle factors like easy access to high-caloric food and a decrease in daily activity cause a growing number of people to be overweight and obese [1–3]. This imbalance in energy consumption and expenditure is supported by the age-related change in body composition from the age of 30 [5, 6]. An increase in body weight (BW) and fat mass (FM) with a redistribution of body fat can be seen between the ages of 30–70 [5, 7, 8]. Simultaneously, the age-related loss of skeletal muscle mass (SMM) leads to a higher risk of falls and fractures and can cause sarcopenia in older age [9]. As changes in body composition already occur in middle adulthood, early preventive strategies such as dietary modification can be implemented to either maintain BW, FM, and SMM in individuals with a normal weight, or to initiate measures aimed at reducing excess FM in overweight individuals, thereby minimizing the risk of developing obesity.

The most important factor for weight loss is a calorie deficit, regardless of the strategy used to achieve it [10]. However, an adequate protein intake is necessary for preserving muscle mass [11]. For adults, the current recommended dietary allowance (RDA) for protein is 0.8 g per kg BW per day [12]. Many dietary approaches can help to reduce BW and FM and improve health outcomes, but the adherence rates in the long-term are low [13]. For successful therapy and prevention, it's important that a program can be easily integrated into everyday life to change the lifestyle in the long term. Also, the exclusion of certain food groups and reduced meal portions can cause hunger and dissatisfaction [14, 15]. However, continuous calorie restriction also entails certain risks. In particular, for individuals with normal-weight, a prolonged low energy availability may lead to deficiencies in macro- and micronutrients as well as a loss of SMM which could increase the risk of falls and fractures [16–18] Two types of diet that do not require reducing the meal portions and avoiding certain food groups are the volumetrics diet (VD) and time-restricted eating (TRE). Therefore, these two concepts could work not only as a short-term measure for weight reduction but also as long-term diets for the prevention of age-related gain in FM [19, 20].

VD is based on a reduced dietary energy density [21]. The energy density of food is defined as the amount of energy (in kcal or kJ) in a given weight (e.g. g or 100 g) of food. An energy density of up to 1.5 kcal/g, i.e. a maximum of 150 kcal per 100 g, is classified as a low energy density [22]. By reducing dietary energy density, a caloric deficit can be achieved [15]. The aim is to be able to eat to satiety with low-calorie, nutrient-dense foods. A study by Rolls & Bell (1999) indicates that it's also the volume of food and not only its energy content that influences satiety. Reduced hunger and a decreased total energy intake were detected with a simultaneous moderate loss in BW and FM in overweight and obese people in short- and long-term observations [23, 24]. The review of Pérez-Escamilla et al. (2012) showed positive associations between low energy density and greater weight loss, better weight maintenance or lower weight increase in many studies [25]. Other studies showed no difference in weight loss between low energy density and other dietary strategies [25, 26].

TRE is a form of intermittent fasting that restricts food intake to specific time periods of the day [27]. The best-known form of TRE is the 16:8 method, in which calorie intake is limited to 8 h daily [28]. In the remaining 16 h of the day, only drinks such as water, unsweetened tea, coffee and calorie-free soft drinks are permitted. Previous studies demonstrated a reduction in overall calorie consumption when implementing TRE with a decrease in BW and FM [28–32]. However, the effects on BW, FM and lean body mass (LBM) are inconclusive in these studies.

Previous studies have investigated the effects of VD or TRE in individuals with obesity who did not engage in regular activity [23, 30, 33]. As previously mentioned, changes in body composition and energy metabolism begin as early as the fourth decade of life. Furthermore, the prevalence of being overweight continues to increase, which is associated with a heightened long-term risk of developing obesity.

To date, no studies examined the impact of both nutrition strategies on normal weight and overweight individual- who are physically active prior to the intervention and maintain their exercise routines throughout the intervention period. Therefore, this study aimed to investigate the effects of VD and TRE on body composition parameters and adherence without altering the physical activity in middle-aged normal weight to overweight physically active adults.

Materials and methods

Study design

The study was conducted as a randomized controlled trial for 12 weeks. The primary parameters BW, relative and absolute FM, LBM, BMI, waist circumference (WC) and hip circumference (HC) were measured at baseline (T0), after 4 weeks (T1), 8 weeks (T2) and 12 weeks (T3). A one-week familiarization phase was conducted before the intervention phase to get the subjects used to the food documentation with the Food Database app (FDDB) (Food Database GmbH, 28217 Bremen, Germany). This phase is not included in the statistical analysis because subjects had to continue their normal diet and were not divided into one of the nutritional concepts. After the familiarization phase, participants were assigned to the VD or TRE group to perform the dietary strategy for 12 weeks. They were supervised by a nutrition coach and documented their nutrition daily with FDDB. The study was approved by the local ethics committee of the IST University of Applied Sciences Dusseldorf, Germany (No. 082023IST233, approved in December 2023) and has been registered in the German registry for clinical studies (DRKS00033809). The study took place between January 2024 and April 2024. The study design can be seen in Fig. 1.

Participants

Physically active participants between 30 and 65 years were recruited with an email newsletter sent to all customers of Bi PHiT GmbH (Munich, Germany). Inclusion criteria were exercising one to three times a week and a BMI between 18,5 and 34,9 kg/m^2. The exclusion criteria were chronic illnesses and acute injuries, pregnancy, eating disorders and smoking. All participants were informed about the study procedure and provided written informed consent before participating. After participants were checked for suitability and completed the familiarization phase, they were randomized into VD and TRE groups based on gender, age and body weight.

Physical activity

At the beginning of the study, participants had to report on the type of sports and the number of training sessions they completed per week. One training session was defined as 60 min. During the study period, it was mandatory for participants to not change their training frequency and type of sports.

Dietary strategies

All participants received information about nutritional basics (energy balance, macronutrients and micronutrients) and were instructed in their specific dietary concepts before the study. They were supervised by a nutrition coach during the whole intervention. Both groups had to document their diet with the FDDB app every day. FDDB is a validated application for dietary analysis [34]. The basal metabolic rate of each subject was calculated using the Benedict-Harris Eq. [35]. To approximate the total energy expenditure, this value was multiplied by the physical activity level (PAL) factor [36]. The PAL factor of every participant was estimated from their reported physical activity. No explicit recommendations were given for the macronutrient, fiber or calorie intake. The calorie target of each person was set to 6000 kcal in the app to not restrict the subjects' eating behavior. No

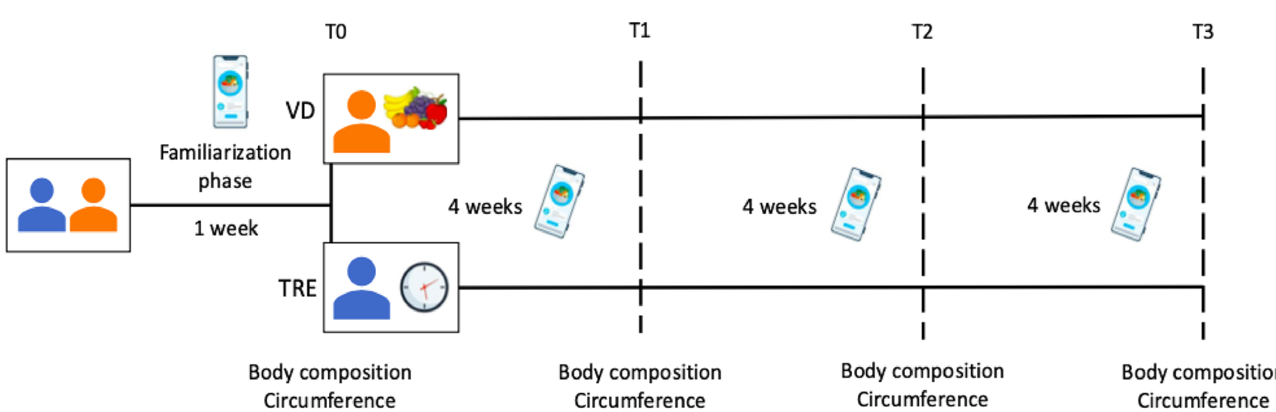

Fig. 1 Study design. TRE, time restricted eating; VD, volumetrics diet

explicit recommendations were given for the macronutrient, fiber or calorie intake, either in the app or otherwise. The app was only be used as a documentation tool.

The participants in the VD group had to ensure an energy density of no more than 1.5 kcal/g in each meal [22]. They were given instructions for calculating the energy density and a table listing the energy density of numerous common foods. They were allowed to eat and combine any food while maintaining a low energy density. Only energy-containing drinks such as alcohol, juices and soft drinks were forbidden. Participants in the TRE group were required to consume their calories between 11:30 AM and 7:30 PM with a possible deviation of half an hour. They were free in their food and drink selection during this time window. In the 16-hour fasting period, they were allowed to consume drinks such as water, unsweetened tea, coffee and calorie-free soft drinks.

Measurements - body composition

The primary parameters BW, FM, LBM, WC and HC were measured every four weeks (T0-T3) in the studio of Bi PHiT GmbH in Munich. The measurements took place between 7.00 and 11.00 A.M. Participants came fasted and were instructed to drink only 0.5 L of water. BW, FM and LBM were measured using a bioelectrical impedance analysis (BIA) (TANITA BC-601 CG; Tanita Corporation, Tokyo, Japan). The BMI was calculated with the following Eq. [37]:

$$BMI\,(\mathrm{kg/m^2}) = \frac{Body\ weight\ \ (kg)}{\left(Height\,(m)^2\right)}$$

WC was measured at the narrowest part of the waist and HC at the thickest part of the buttocks, both with a measuring tape. In addition, the waist-to-height ratio (WHR) was calculated at each measurement by dividing the waist circumference of each subject by their height. The WHR is a measurement tool to help assess central obesity in adults with a BMI below 35 kg/m^2 [38]. Central obesity is categorised into three degrees depending on the waist-to-height ratio: healthy central adiposity with a WHR of 0.4 to 0.49, increased central adiposity with a WHR of 0.5 to 0.59 and high central adiposity with a WHR of 0.6 or more. The last two degrees are indicating an increased health risk with type 2 diabetes, hypertensions and cardiovascular disease.

Adherence

To investigate the adherence and feasibility of VD and TRE in everyday life, a questionnaire was sent to the participants every Sunday. They had to self-report how many days they could stick to their dietary concept the previous week. In the VD group, a day was considered non-adherent when there was a meal with an energy density over 1.5 kcal/g. In the TRE group, a day was non-adherent when food or calorie-rich drinks were consumed during the fasting period. Both groups had to give reasons for not complying with the concept. They had to rate the feasibility of the diet in their everyday life on a scale of 1–5 (1 = It was very difficult for me; 5 = It was very easy) for the previous week. They were also asked to describe their mood and well-being in the questionnaire such as sleep quality, energy level during the day or feeling of hunger. The weekly questionnaire can be found in the supplemental material.

Statistical analysis

A priori power analysis was performed with G*Power version 3.1.9.6 (*F*-Test, ANOVA: Repeated measures, within-between interaction). A moderate effect ($f = 0.25$), an α-error of 0.05, a power of $\beta = 0.95$, two groups and four measurements were used for the calculation. The correlation between repeated measures was set to 0.5 and the nonsphericity correction ε to 1. The estimated minimum sample size was 36 participants.

All statistical analyses were conducted using R (Version 4.4.1, R Core Team, 2023). The parameters were tested for normal distribution with the Shapiro-Wilk test. Baseline characteristics, dietary intake and adherence to the dietary concepts between the groups were analyzed by independent samples t-test. The changes in adherence to the concepts in each group over time were tested with the paired t-test. The Mann-Whitney-*U*-Test was used to examine differences in training frequency between VD and TRE. Linear mixed-effect models (LMM) were used to analyze differences in the body composition and circumference variables between the groups (VD vs. TRE), for time (T0, T1, T2, T3) and in their interaction (time*group). The lme4 package was used in R [39]. The variable time was classified as a continuous variable as it was assumed to have a linear effect over the intervention phase. The variable group was categorized as a factor with two levels (VD and TRE). A significant difference between the groups at baseline showed up as a group effect. Significant changes over time, regardless of group, were reported as time effects and a significant change between the groups over time was assumed as an interaction effect. The variables training frequency and sex were added as a fixed covariate of no interest. To analyze the influence of protein intake on the development of LBM, participants were divided into three groups based on their daily protein intake (Group 1: < 0.8 g/kg BW; Group 2: 0.8–1.2 g/kg BW; Group 3: >1.2 g/kg BW). A regression analysis was used to detect any difference in the change of the LBM between the three groups over the intervention period.

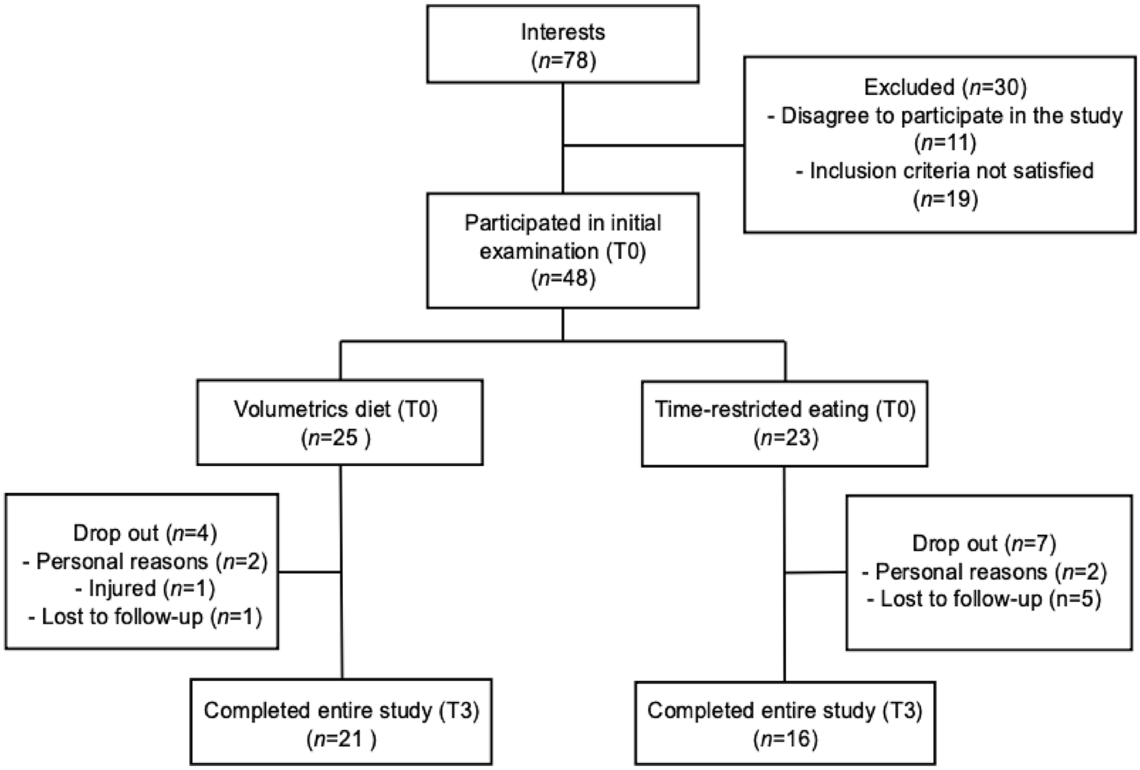

Fig. 2 Participant flow diagram

Table 1 Baseline characteristics of participants

Parameter	VD (*n* = 21)	TRE (*n* = 16)	*p*-value
Male	4	7	
Female	17	9	
Age (years)	39.48 ± 8.83	42.06 ± 8.47	< 0.001*
Height (cm)	170.43 ± 7.68	172.50 ± 7.64	< 0.001*
Body weight (kg)	73.59 ± 12.80	78.99 ± 13.49	0.200
Fat mass (kg)	21.00 ± 7.66	21.97 ± 6.24	0.664
Fat mass (%)	28.33 ± 7.72	27.71 ± 6.31	0.795
Lean body mass (kg)	49.95 ± 9.76	54.11 ± 10.27	0.214
BMI (kg/m2)	25.38 ± 4.37	26.38 ± 2.81	0.404
Waist circumference (cm)	81.02 ± 11.30	85.03 ± 9.76	0.237
Hip circumference (cm)	102.55 ± 7.91	104.88 ± 7.59	0.362

Data are presented as mean ± standard deviation

*indicates a significant difference between groups

BMI, body mass index; TRE, time-restricted eating; VD, volumetrics diet

A p-value of < 0.05 was defined as statistical significance [40]. Effect sizes (d) were calculated with Cohen's d for the changes in body composition per group over the intervention period. Effect sizes are classified as trivial ($d < 0.2$), small ($0.2 \leq d < 0.5$), medium ($0.5 \leq d < 0.8$) and large ($d \geq 0.8$) [41].

Results

Seventy-eight individuals registered via the newsletter (Fig. 2). 30 interests were excluded because the inclusion criteria weren't satisfied ($n = 19$) or they disagreed with participating in the study after receiving detailed information about the conditions ($n = 11$). 48 subjects attended the initial measurement. 11 people dropped out during the intervention phase and a total of 37 participants (VD = 21; TRE = 16) completed the entire study. In the VD group, 17 women and 4 men participated, while the TRE group comprised 9 women and 7 men. At baseline, a significant difference in age ($p < 0.001$) and height ($p < 0.001$) was detected between the groups. No differences were detected in any other parameters at T0. All participant characteristics at baseline are presented in Table 1.

Physical activity

The types of sports participants reported in the questionnaire were classified into three categories: strength training, endurance training and other physical activity. The category "other physical activity" included sports such as yoga or tennis that couldn't be assigned clearly as strength or endurance training. The number of training sessions per week per group was calculated in total and for each category. There was no significant difference in the total training frequency between the groups. For the different training types, no significant difference was detected between VD and TRE.

With these results, participants didn't meet the guidelines on physical activity from the World Health Organization (WHO) of 150–300 min of moderate-intensity or

Table 2 Training frequency for different training type categories and in total

Training type	VD	TRE	*p*-value
Strength training (TS/week)	1.76 ± 1.00	1.56 ± 0.96	0.495
Endurance training (TS/week)	0.48 ± 0.60	0.50 ± 0.63	0.944
Other physical activity (TS/week)	0.67 ± 0.91	0.56 ± 0.63	0.999
Training frequency (TS/week)	2.90 ± 0.94	2.62 ± 1.09	0.462

Data are presented as mean ± standard deviation. A training session is defined as a duration of 60 min

TRE, time-restricted eating; TS, training sessions; VD, volumetrics diet

75–150 min of vigorous-intensity aerobic physical activity [42]. On average, they also didn't meet the recommendations for strength training of at least two days a week. Table 2 shows the training frequency and the allocation to the specific categories per group.

Measurements - body composition

BW changed significantly from pre- to post-intervention in both groups ($p = 0.0002$; $d = 0.61$), but no significant difference was detected between the groups or in the interaction effect. Significant time effects were also observed in absolute ($p < 0.0001$; $d = 0.85$) and relative FM ($p < 0.0001$; $d = 0.84$), BMI ($p = 0.0001$; $d = 0.60$), WC ($p < 0.0001$; $d = 0.92$), HC ($p = 0.003$; $d = 0.51$) and WHR ($p < 0.0001$; $d = 0.90$). No significant group or interaction effect was detected in any of these parameters. There was no significant time, group and interaction effect for LBM. All body composition parameters at every measurement time can be seen in Table 3. Figures 3A-G show the change in each parameter per group during the intervention phase.

Dietary intake

The evaluation of the FDDB app showed no significant difference in the average calorie intake between the groups. Also, no significant difference was detected in average fat, carbohydrate, and protein intake between VD and TRE. The daily calorie deficit was calculated by subtracting the daily calorie intake of every individual from their energy requirement. The average calorie deficit was 184.19 ± 634.95 kcal/d for VD and 113.50 ± 410.62 kcal/d for TRE. In the VD group, the average protein intake was 1.13 ± 0.41 g/kg BW per day. The TRE group consumed 0.93 ± 0.34 g/kg BW daily. Between the groups was no significant difference in the daily protein intake per kg of body weight.

The regression analysis showed no significant influence of protein intake on the development of LBM between the three groups separated by their daily protein intake.

Table 3 Body composition parameters per group at every measurement time

Parameter	T0 Pre-intervention	T1 (4 weeks)	T2 (8 weeks)	T3 Post-intervention (12 weeks)	*p*-value (group)	*p*-value (time T0-T3)	ES (d) (time T0-T3)	*p*-value (I)
Body weight (kg)								
VD	73.59 ± 12.80	72.00 ± 12.14	71.75 ± 12.17	71.97 ± 11.88	0.200	0.0002*	0.61	0.832
TRE	78.99 ± 13.49	77.84 ± 13.10	77.04 ± 12.45	77.23 ± 11.85				
Fat mass (kg)								
VD	21.00 ± 7.66	19.27 ± 7.37	19.06 ± 6.81	18.86 ± 6.94	0.664	< 0.0001*	0.85	0.629
TRE	21.97 ± 6.24	20.70 ± 5.91	20.77 ± 5.69	20.11 ± 5.61				
Fat mass (%)								
VD	28.33 ± 7.72	26.52 ± 7.58	26.44 ± 7.17	26.08 ± 7.49	0.795	< 0.0001*	0.84	0.307
TRE	27.71 ± 6.31	26.56 ± 6.45	27.03 ± 6.58	26.13 ± 6.57				
Lean body mass (kg)								
VD	49.95 ± 9.76	50.08 ± 9.35	50.05 ± 9.65	50.40 ± 9.69	0.214	0.139	0.24	0.497
TRE	54.11 ± 10.27	54.27 ± 10.45	53.46 ± 10.36	54.25 ± 10.23				
BMI (kg/m^2)								
VD	25.38 ± 4.37	24.83 ± 4.12	24.74 ± 4.12	24.81 ± 4.04	0.404	0.0001*	0.60	0.973
TRE	26.38 ± 2.81	25.99 ± 2.63	25.74 ± 2.49	25.82 ± 2.39				
Waist circumference (cm)								
VD	81.02 ± 11.30	79.31 ± 9.90	77.45 ± 10.43	77.19 ± 9.43	0.237	< 0.0001*	0.92	0.241
TRE	85.03 ± 9.76	83.69 ± 10.28	82.31 ± 9.68	82.31 ± 9.14				
Hip circumference (cm)								
VD	102.55 ± 7.91	101.88 ± 8.01	100.24 ± 8.52	100.31 ± 7.92	0.362	0.003*	0.51	0.947
TRE	104.88 ± 7.59	104.86 ± 6.59	102.75 ± 7.72	102.56 ± 5.46				
Waist-to-height ratio								
VD	0.48 ± 0.07	0.47 ± 0.06	0.46 ± 0.07	0.45 ± 0.06	0.408	< 0.0001*	0.90	0.210
TRE	0.49 ± 0.04	0.48 ± 0.05	0.48 ± 0.04	0.48 ± 0.04				

Data are presented as mean ± standard deviation. *p*-values are from linear mixed-effect models. *indicates a significant difference

BMI, body mass index; ES, effect size; I, interaction effect; TRE, time-restricted eating; VD, volumetrics diet

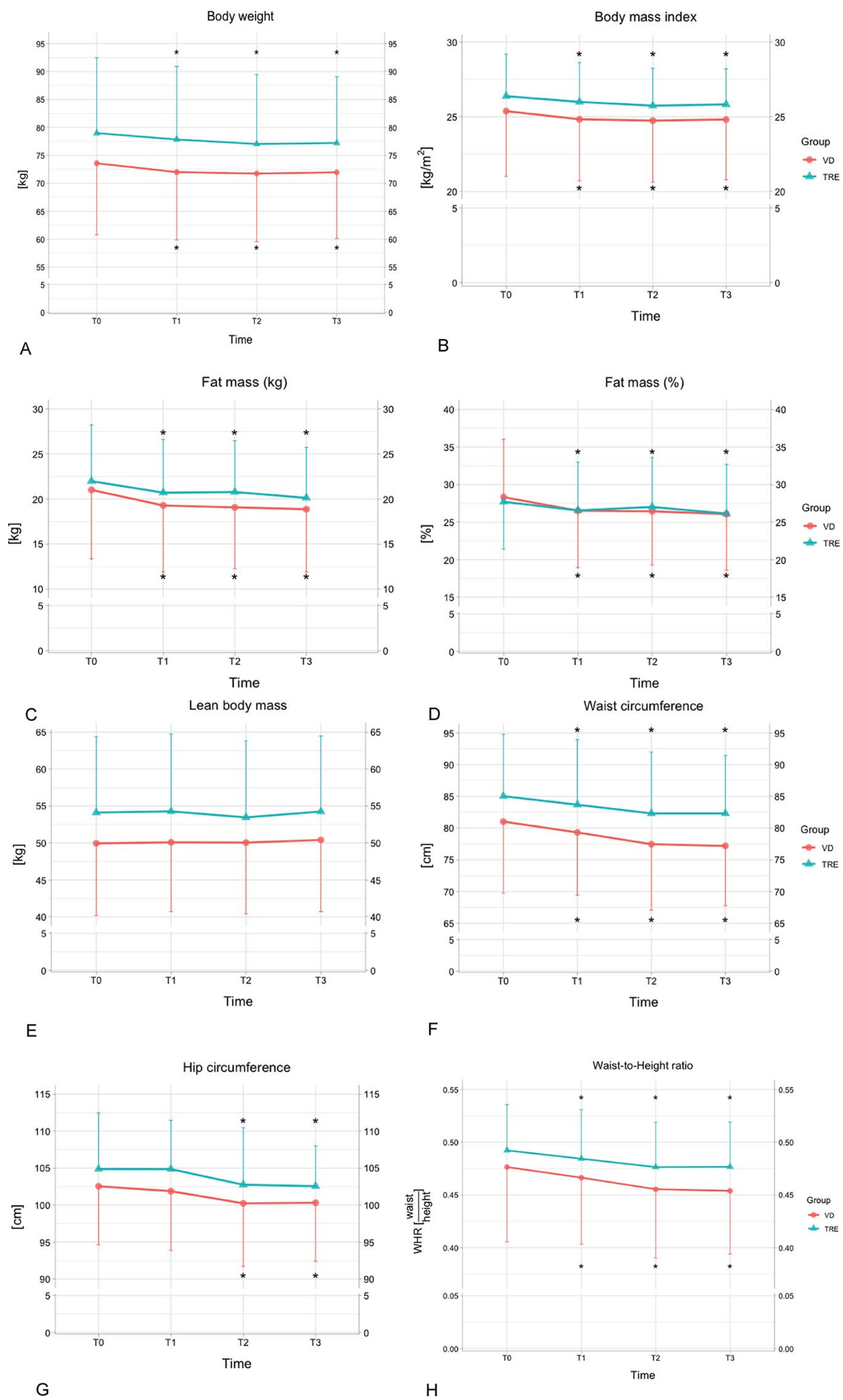

Fig. 3 **A-H** Changes in body composition over time (T0-T3), separated by group. (**A**) body weight, (**B**) body mass index, (**C**) absolute fat mass (kg), (**D**) relative fat mass (%), (**E**) lean body mass, (**F**) waist circumference, (**G**) hip circumference, (**H**) Waist-to-height ratio. *indicates a significant difference to T0. Data were analyzed using linear mixed-effects models. TRE, time-restricted eating; VD, volumetrics diet

Table 4 Dietary intake per group

Macronutrient	VD	TRE	*p*-value
Kilojoule			
(kJ/d)	7083.72 ± 1530.58	7452.45 ± 2395.97	0.650
(kJ/kg BW)	96.94 ± 20.05	95.05 ± 18.97	
Kilocalories			
(kcal/d)	1691.84 ± 365.55	1779.90 ± 572.24	0.650
(kcal/kg BW)	23.20 ± 4.64	23.10 ± 5.30	
Fat			
(g/d)	64.47 ± 16.77	73.47 ± 29.18	0.362
(g/kg BW)	0.88 ± 0.22	0.94 ± 0.26	
Carbohydrate			
(g/d)	174.44 ± 46.04	186.74 ± 55.51	0.537
(g/kg BW)	2.39 ± 0.59	2.44 ± 0.61	
Protein			
(g/d)	84.29 ± 32.12	75.65 ± 32.12	0.460
(g/kg BW)	1.16 ± 0.39	0.97 ± 0.32	

Data are presented as mean ± standard deviation

BW, body weight; TRE, time-restricted eating; VD, volumetrics diet

The absolute and relative dietary intake per group is shown in Table 4.

Adherence

The self-reported weekly questionnaire showed a significantly higher adherence rate for TRE with 5.78 ± 1.13 days per week compared to VD with 5.29 ± 1.49 days per week ($p = 0.0002$; $d = 0.362$). From the first week to the last week, the adherence of VD dropped from 74 to 65%. This change over time in the group was not significant ($p = 0.253$). In TRE, the adherence dropped from 90 to 77% over the intervention phase, also not significantly ($p = 0.202$).

Discussion

This study aimed to investigate the effect of two dietary concepts VD and TRE on body composition in middle-aged physically active individuals. The results showed significant decreases for the primary parameters BW, absolute and relative FM, BMI, WC, HC and WHR in both groups after the 12-week intervention phase. No significant group difference was detected for any primary parameter. Both groups maintained their LBM. Previous studies support these observations of a reduction in BW and FM for both dietary approaches in individuals with overweight or obesity [23, 24, 29, 30, 43]. The findings in the present study indicate that both concepts are not only suitable as therapeutic methods against obesity but also as prevention strategies to reduce the age-related FM increase in individuals with normal-weight to overweight [44]. Besides diet, physical activity also has an impact on calorie expenditure. Participants in this study didn't meet the recommendations of the WHO for physical activity. Compliance with these guidelines could impact the primary parameters and other health outcomes and may have led to a greater reduction in BW and FM [42].

The individuals trained two to three times per week, including at least one strength training session. The combination of TRE and exercise also led to a decrease in FM and a preservation of SMM in previous studies [43, 44]. The review of Kang et al. (2022) reported that in three out of eleven studies a significant loss in SMM during TRE in participants who are overweight or obese [45]. In these three studies, no specific training program was performed. A lack of studies makes it hard to apply the potential effects of VD on normal-weight, physically active people. In a study for weight loss with VD, individuals with overweight could maintain their SMM while reducing their BW [26]. Overall, these findings suggest VD and TRE could work as prevention strategies against age-related loss of SMM if an appropriate training program is practised simultaneously. A bigger training stimulus is probably needed to increase SMM [46].

The dietary analysis showed a calorie deficit of 184.19 ± 634.95 kcal/d for VD and 113.50 ± 410.62 kcal/d for TRE, although reaching a deficit was not specifically required. These findings suggest that both VD and TRE can lead to a calorie deficit only by following the concept without specific limits for calorie intake. For weight loss in obese individuals living with obesity, a deficit of 500 to 700 kcal/d is recommended [47]. However, a high calorie deficit can cause muscle loss which should be avoided due to a higher risk of fatigue and injuries, declines in muscular function and a lower resting calorie expenditure [11]. An article by Rolls & Bell (2000) concludes that an optimal weight loss program should avoid an extreme caloric deficit, satisfy hunger, and consider food preferences and nutritional needs. VD and TRE both meet these criteria. But there's a risk that the calorie deficit will become even smaller or disappear as adherence to the concept declines. For maintaining or building SMM, daily protein intake is an important factor [11]. Both groups are slightly above the current RDA for daily protein intake. However, recent studies suggest even higher intakes of 1.2–1.6 g/kg BW per day for optimal health outcomes in adults [48]. In those studies, groups with a protein intake of 16–45% (i.e. 1.2–1.6 g/kg BW daily) showed greater BW and FM loss and maintained more LBM compared to the control group with a normal protein intake of 5–23%. Based on the results of the regression analyses in this study, the daily protein intake did not influence the development of LBM over 12 weeks. However, the caloric deficit in this study was small and the influence of protein intake on preservation of LBM may be more important with larger caloric deficits [49].

The adherence and feasibility of both concepts in everyday life were tested as well. Both dietary approaches were largely successfully implemented within the interventions and integrated into the participants' daily routines. Accordingly, both strategies can be considered preventive approaches to weight regulation that may be effective without explicitly focusing on energy intake. Adherence to the respective dietary interventions resulted in significant reductions in FM, BMI, and WHR in both groups. BMI and WHR are recognized anthropometric markers for the classification of overweight and obesity. At baseline, both groups were positioned at the borderline between normal-weight and overweight according to both measures. The dietary modifications led to comparable improvements in BMI and WHR across the groups. A significant difference in adherence was detected between the groups with a higher adherence for the TRE group. In both groups, the percentage of compliance dropped over the 12 weeks, but not significantly. However, the decreasing adherence could explain the plateau in almost every primary parameter after the first four weeks. Recent studies for TRE show similar results, where high adherence to the fasting window shows a significant loss of BW, FM, visceral FM or BMI when comparing TRE with a non-TRE control group [30, 33]. Lowe et al. (2014) detected a significant weight loss in both the VD and meal-replacement groups, but significantly lower weight regains in the VD group in the 2-year follow-up [50].

Based on the results of this study, it can be assumed that VD has the same effects on body composition changes as TRE with less adherence. There are currently no studies comparing VD and TRE. Therefore, further studies should be conducted to support or refute these assumptions. However, adherence to the strategies seems to be a decisive factor for the effectiveness of both concepts. It can be assumed that a higher adherence rate could have led to greater changes in the primary parameters. Even if the strategies are not completely compatible with everyday life, they still show potential benefits when following them as good as possible.

Limitations

Although the present study indicates potential benefits of VD and TRE against age-related changes in body composition in middle-aged healthy individuals, it also has some limitations. First, the sample size is too small to make any final conclusions for the entire population. Nevertheless, the observations are largely consistent with those of other studies [23, 25, 29, 33]. Moreover, the sample size for both sexes was too small to conduct subgroup analyses of effects in men and women. However, LMM revealed no significant differences between the sexes, suggesting that no substantial sex-related differences were present in this study. Another limitation of this study was the self-reported nutritional documentation. Although it was with a validated nutrient tracker (FDDB app), underreporting of consumed food cannot be ruled out [34]. The same applies to the adherence questionnaire where participants had to self-report how many days they complied with their concept. Especially for VD, it isn't easy to guarantee an energy density of no more than 1.5 kcal/g in a meal with different food combinations. Also, the use of the FDDB app may have influenced the food choices of the participants [34].

Further studies should have more controlled training regimes, as this study just advised not to change physical behavior during the study period. Individual differences in training frequency and type of sports between the participants might influence the changes in body composition. Also, the calculation of energy requirement with the Harris-Benedict equation and the estimation of the PAL factor can deviate from the actual needs and therefore falsify the individual calorie deficit [51].

Conclusion

Based on the results of this study, it can be assumed that VD leads to the same effects as TRE with a lower level of adherence in a 12-week intervention. Both dietary strategies reduced BW, FM, BMI, WC, HC and WHR in middle-aged normal-weight to overweight adults. However, the sample size is too small to make any final conclusions. Adherence to the concepts appeared to be an important factor in success and a longer study period is needed to observe any differences in the outcomes. All participants were physically active adults and continued their regular training during the study period. Both groups maintained their LBM. These findings suggest that VD and TRE are potential dietary approaches to counteract age-related changes in body composition and can be used as long-term measures with good adherence.

Abbreviations

BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
BW	Body Weight
ES	Effect Size
FDDB	Food Database App
FM	Fat Mass
HC	Hip Circumference
I	Interaction Effect
LBM	Lean Body Mass
LME	Linear Mixed-Effect Models
PAL	Physical Activity Level
RDA	Recommended Dietary Allowance
SMM	Skeletal Muscle Mass
TRE	Time-Restricted Eating
TS	Training Sessions
VD	Volumetrics Diet
WC	Waist Circumference
WHO	World Health Organization
WHR	Waist-to-Height Ratio

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Author contributions

A.C. main investigator, study design, statistical analyses and preparation of the manuscript; S.G.; = study design, and preparation of the manuscript—proof reading. E.I. supervision, study design, and preparation of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Informed consent

Informed consent was obtained from all subjects involved in the study.

Declarations institutional review board

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the ethics of IST University of Management Dusseldorf, Germany (No. 082023IST233, approved in December 2023) and has been registered in the German registry for clinical studies (DRKS00033809).

Competing interest

The authors declare no competing interests.

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References

1. Arroyo-Johnson C, Mincey KD. Obesity epidemiology worldwide. Gastroenterol Clin N Am. 2016;45(4):571–9.
2. Phelps NH, Singleton RK, Zhou B, Heap RA, Mishra A, Bennett JE, et al. Worldwide trends in underweight and obesity from 1990 to 2022: a pooled analysis of 3663 population-representative studies with 222 million children, adolescents, and adults. Lancet. 2024;403(10431):1027–50.
3. World Health Organization. Global status report on noncommunicable diseases 2014. Geneva: World Health Organization; 2014. p. 280.
4. Lehnert T, Sonntag D, Konnopka A, Riedel-Heller S, König HH. Economic costs of overweight and obesity. Best Pract Res Clin Endocrinol Metab. 2013;27(2):105–15.
5. Bemben MG, Massey BH, Bemben DA, Boileau RA, Misner JE. Age-related patterns in body composition for men aged 20–79 year. Med Sci Sports Exerc. 1995;27(2):264–9.
6. Hughes VA, Roubenoff R, Wood M, Frontera WR, Evans WJ, Fiatarone Singh MA. Anthropometric assessment of 10-y changes in body composition in the elderly. Am J Clin Nutr. 2004;80(2):475–82.
7. Hunter GR, Gower BA, Kane BL. Age related shift in visceral fat. Int J Body Compos Res. 2010;8(3):103–8.
8. Lexell J, Taylor CC, Sjöström M. What is the cause of the ageing atrophy? J Neurol Sci. 1988;84(2–3):275–94.
9. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis. Age Ageing. 2010;39(4):412–23.
10. Hauner H, Moss A, Berg A, Bischoff S, Colombo-Benkmann M, Ellrott T, et al. Interdisziplinäre leitlinie der qualität S3 Zur„prävention und therapie der adipositas. Adipositas-Ursachen Folgeerkrankungen Ther. 2014;8(04):179–221.
11. Willoughby D, Hewlings S, Kalman D. Body composition changes in weight loss: strategies and supplementation for maintaining lean body mass, a brief review. Nutrients. 2018;10(12):1876.
12. National Research Council, National Research Council, editors. Recommended dietary allowances. 10.ed., 7. print. Washington: National Acad.; 1993. p. 284.
13. Dansinger ML, Gleason JA, Griffith JL, Selker HP, Schaefer EJ. Comparison of the atkins, ornish, weight watchers, and zone diets for weight loss and heart disease risk reduction: A randomized trial. JAMA. 2005;293(1):43.
14. Rolls BJ, Bell EA. Intake of fat and carbohydrate: role of energy density. Eur J Clin Nutr. 1999;53(S1):s166–73.
15. Rolls BJ, Bell EA. Ditary approaches to the treatment of obesity. Med Clin North Am. 2000;84(2):401–18.
16. Schrager MA, Schrack JA, Simonsick EM, Ferrucci L. Association between energy availability and physical activity in older adults. Am J Phys Med Rehabil. 2014;93(10):876–83.
17. Wasserfurth P, Palmowski J, Hahn A, Krüger K. Reasons for and Consequences of Low Energy Availability in Female and Male Athletes: Social Environment, Adaptations, and Prevention. Sports Med - Open [Internet]. 2020 Dec [cited 2025 May 22];6(1). Available from: https://sportsmedicine-open.springeropen.com/articles/https://doi.org/10.1186/s40798-020-00275-6
18. Gallant TL, Ong LF, Wong L, Sparks M, Wilson E, Puglisi JL, et al. Low energy availability and relative energy deficiency in sport: A systematic review and Meta-analysis. Sports Med. 2025;55(2):325–39.
19. Greene LF, Malpede CZ, Henson CS, Hubbert KA, Heimburger DC, Ard JD. Weight maintenance 2 years after participation in a weight loss program promoting Low-Energy density foods**. Obesity. 2006;14(10):1795–801.
20. Manoogian ENC, Chow LS, Taub PR, Laferrère B, Panda S. Time-restricted eating for the prevention and management of metabolic diseases. Endocr Rev. 2022;43(2):405–36.
21. Bechthold A. Food energy density and body Weight - A scientific statement from the DGE. Ernahrungs Umschau. 2014;61(1):2–11.
22. FETeV. Fachgesellschaft für Ernährungstherapie. Energie- und Nährstoffdichte von Lebensmitteln [Internet]. 2023 [cited 2024 Nov 18]. Available from: https://fet-ev.eu/energie-naehrstoffdichte/#:~:text=Wissenswertes-,Energiedichte%3A%20Beurteilung%20Energiegehalt,und%20250%20kcal%20sind%20energiemoderat
23. Ello-Martin JA, Roe LS, Ledikwe JH, Beach AM, Rolls BJ. Dietary energy density in the treatment of obesity: a year-long trial comparing 2 weight-loss diets. Am J Clin Nutr. 2007;85(6):1465–77.
24. Yao M, Roberts SB. Dietary energy density and weight regulation. Nutr Rev. 2009;59(8):247–58.
25. Pérez-Escamilla R, Obbagy JE, Altman JM, Essery EV, McGrane MM, Wong YP, et al. Dietary energy density and body weight in adults and children: A systematic review. J Acad Nutr Dietetics. 2012;112(5):671–84.
26. Melanson KJ, Summers A, Nguyen V, Brosnahan J, Lowndes J, Angelopoulos TJ, et al. Body composition, dietary composition, and components of metabolic syndrome in overweight and obese adults after a 12-week trial on dietary treatments focused on portion control, energy density, or glycemic index. Nutr J. 2012;11(1):57.
27. Anton SD, Moehl K, Donahoo WT, Marosi K, Lee SA, Mainous AG, et al. Flipping the metabolic switch: Understanding and applying the health benefits of fasting: flipping the metabolic switch. Obesity. 2018;26(2):254–68.
28. Aragon AA, Schoenfeld BJ. Does timing matter?? A narrative review of intermittent fasting variants and their effects on bodyweight and body composition. Nutrients. 2022;14(23):5022.
29. Antoni R, Robertson TM, Robertson MD, Johnston JD. A pilot feasibility study exploring the effects of a moderate time-restricted feeding intervention on energy intake, adiposity and metabolic physiology in free-living human subjects. J Nutr Sci. 2018;7:e22.
30. Gabel K, Hoddy KK, Haggerty N, Song J, Kroeger CM, Trepanowski JF, et al. Effects of 8-hour time restricted feeding on body weight and metabolic disease risk factors in obese adults: A pilot study. NHA. 2018;4(4):345–53.
31. Kang J, Ratamess N, Faigenbaum A, Bush J, Beller N, Vargas A, et al. Effect of Time-Restricted feeding on anthropometric, metabolic, and fitness parameters: A systematic review. J Am Coll Nutr. 2021;41:1–16.
32. Rynders CA, Thomas EA, Zaman A, Pan Z, Catenacci VA, Melanson EL. Effectiveness of intermittent fasting and Time-Restricted feeding compared to continuous energy restriction for weight loss. Nutrients. 2019;11(10):2442.
33. Chow LS, Manoogian ENC, Alvear A, Fleischer JG, Thor H, Dietsche K, et al. Time-Restricted eating effects on body composition and metabolic measures in humans who are overweight: A feasibility study. Obesity. 2020;28(5):860–9.
34. Baum Martinez I, Peters B, Schwarz J, Schuppelius B, Steckhan N, Koppold-Liebscher DA, et al. Validation of a smartphone application for the assessment of dietary compliance in an intermittent fasting trial. Nutrients. 2022;14(18):3697.
35. Harris JA, Benedict FG. A biometric study of human ang J, Ratamess NA, F basal metabolism. Proc Natl Acad Sci USA. 1918;4(12):370–3.

36. German Nutrition Society (DGE). New reference values for energy intake. Ann Nutr Metab. 2015;66(4):219–23.
37. Weir CB, Jan A. In: StatPearls, editor. BMI classification percentile and cut off points. Treasure Island (FL): StatPearls Publishing. 2024.
38. National Institute for Health and Care Excellence. Overweight and obesity management [Internet]. NICE; 2025 Jan [cited 2025 May 16]. Report No.: NG246. Available from: https://www.nice.org.uk/guidance/ng246
39. Bates D, Mächler M, Bolker B, Walker S. Fitting linear Mixed-Effects models using lme4. J Stat Soft. 2015;67(1).
40. Fisher RA. Statistical Methods for Research Workers. Oliver and Boyd. 1925. (Biological monographs and manuals).
41. Cohen J. Statistical power analysis for the behavioral sciences. 0 ed. Routledge. 2013.
42. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World health organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020;54(24):1451–62.
43. Kotarsky CJ, Johnson NR, Mahoney SJ, Mitchell SL, Schimek RL, Stastny SN et al. Time-restricted eating and concurrent exercise training reduces fat mass and increases lean mass in overweight and obese adults. Physiol Rep. 2021;9(10).
44. Moro T, Tinsley G, Bianco A, Marcolin G, Pacelli QF, Battaglia G, et al. Effects of eight weeks of time-restricted feeding (16/8) on basal metabolism, maximal strength, body composition, inflammation, and cardiovascular risk factors in resistance-trained males. J Transl Med. 2016;14(1):290.
45. Kang J, Ratamess NA, Faigenbaum AD, Bush JA, Beller N, Vargas A, et al. Effect of Time-Restricted feeding on anthropometric, metabolic, and fitness parameters: A systematic review. J Am Nutr Association. 2022;41(8):810–25.
46. Kumar V, Atherton P, Smith K, Rennie MJ. Human muscle protein synthesis and breakdown during and after exercise. J Appl Physiol. 2009;106(6):2026–39.
47. Jensen MD, Ryan DH, Apovian CM, Ard JD, Comuzzie AG, Donato KA, et al. 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults. J Am Coll Cardiol. 2014;63(25):2985–3023.
48. Phillips SM, Chevalier S, Leidy HJ. Protein requirements beyond the RDA: implications for optimizing health. Appl Physiol Nutr Metab. 2016;41(5):565–72.
49. Soenen S, Martens EAP, Hochstenbach-Waelen A, Lemmens SGT, Westerterp-Plantenga MS. Normal protein intake is required for body weight loss and weight maintenance, and elevated protein intake for additional preservation of resting energy expenditure and fat free mass. J Nutr. 2013;143(5):591–6.
50. Lowe MR, Butryn ML, Thomas JG, Coletta M. Meal replacements, reduced energy density eating, and weight loss maintenance in primary care patients: A randomized controlled trial. Obesity. 2014;22(1):94–100.
51. Pavlidou E, Papadopoulou SK, Seroglou K, Giaginis C. Revised Harris-Benedict equation: new human resting metabolic rate equation. Metabolites. 2023;13(2):189.

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