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Effects of high-dairy versus low-dairy, high-protein and low-calorie diets combined with aerobic exercise on central body fat in overweight women: A pragmatic randomized controlled trial

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ABSTRACT

Introduction: Obesity is one of the most concerning public health issues, and it is known as a predisposing factor for many chronic cardiometabolic diseases. Overweight individuals should be included in preventative interventions. Combining a high-dairy, high-Protein and low-calorie diet might help reduce appetite and body weight more effectively. We aimed to assess whether this approach, coupled with moderate-intensity aerobic activity, would be more effective in helping overweight women reduce central fat accumulation than a low-dairy diet, high in protein and low in calories.
Methods: This randomized clinical trial recruited young overweight women aged 20–45-year-old, and compared one of two 700 Kcal restricted diet management options: intervention group with a high protein with high amounts of dairy products and 40 g of casein supplement or control group with a high protein, low-dairy diet for two weeks. In addition, moderate-intensity aerobic exercise was individually determined and prescribed for both intervention and control groups. The primary outcomes were a change in abdominal and suprailiac skinfold thickness. The secondary outcomes were body weight; BMI; waist and hip circumferences measured before the trial and after two weeks. Our analysis was based on both the intention-to-treat and per-protocol principles. This trial was registered with the Tehran University of Medical Sciences (IRCT20201102049229N1).
Results: Between the 20th of January 2021 and the 18th of March 2021, 60 participants were randomly assigned to the intervention or control groups. Forty-seven of them (78%) completed the study. The mean drop in abdominal and suprailiac skinfold thicknesses was −4.82 mm and −3.22 mm, respectively, in the dairy group and −2.83 mm and −2.00, respectively, in the non-dairy group. The adjusted mean difference was −1.99 (95% CI: 0.49–3.48; $p = 0.005$) in abdominal skinfold thickness and −1.22 (95% CI: 0.06–2.38; $p = 0.017$) in suprailiac skinfold thickness in favour of the high-dairy group. All other secondary outcomes, including waist circumferences, hip circumference, Mean Body Fat, Percentage Body Fat, Soft Lean Mass, Body Mass Index, Fat

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Mass Index, and Fat-Free Mass Index, showed significant changes ($p < 0.05$) in the intervention group.
Conclusion: High-dairy, low-calorie diet is more effective than a high-protein, low-calorie diet in weight and body fat reduction, particularly central fat, in overweight young adult women.

1. Introduction

The prevalence of obesity and the burden of obesity-related diseases are rising globally. Estimated that over 3 billion people will suffer from obesity by 2030 (Kelly et al., 2008). Moreover, obesity-induced diseases are associated with a high morbidity and mortality rate, which imposes an increased financial burden on patients and the healthcare system (Zhang et al., 2014; Maggio and Pi-Sunyer, 1997). Obesity increases the risk of developing a wide range of chronic non-communicable diseases (NCD), such as type 2 diabetes, heart disease, chronic kidney disease, malignancies, and a range of musculoskeletal conditions, and as a result, is associated with a risk of premature mortality that is approximately 1–3 times higher than in people who are of a healthy weight (Lagerros and Rössner, 2013; Global et al., 2016).

Fat tissue pathologies often described as adiposopathy, can be influenced by genetic factors. Still, lifestyle factors such as physical activity, nutrition, and stress play a more significant role in the general population. Obesity and overweight are associated with increased central body fat, resulting in adipose tissue dysfunction. Increased BMI and abdominal circumference are risk factors for developing adiposopathy and an increased risk of metabolic and cardiovascular disease (Bays, 2011, 2014; Mokha et al., 2010). Given that obesity is linked to a variety of diseases with rising disease burdens, it may be a crucial target for multimorbidity primary prevention, especially when targeting younger higher-risk populations (Kivimaki et al., 2022).

Several diets have been described for weight loss, and fat loss is often prioritized to lean mass gain when trying to lose weight (Giglio et al., 2019). As an example, the effect of high-protein diets on weight loss has been proven (Slentz et al., 2004; Giglio et al., 2019; Abargouei et al., 2012; Hansen et al., 2021), and the most prominent mechanism in these types of diets is appetite control (Hansen et al., 2021; Moon and Koh, 2020), even in long-term weight maintenance (Shariaty et al., 2019). In addition, some studies have assessed the impact of dairy protein on weight loss. It seems that increased consumption of dairy products, such as milk and yoghurt, can increase lean body mass and, at the same time, reduce fat mass (Abargouei et al., 2012). Some studies assessed the mechanism of high-dairy products on fat reduction (Giglio et al., 2019; Abargouei et al., 2012; Zemel et al., 2005). On the one hand, leucine and casein in dairy products help to reduce appetite and maintain muscle mass, leading to weight loss by decreasing body fat (Giglio et al., 2019; Abargouei et al., 2012). On the other hand, there is some evidence of the antiobesity effect of dietary Ca^{2+}, which is due to Ca suppression of calcitriol levels, resulting in reduced adipocyte intracellular Ca^{2+} and, accordingly, a rise in lipid utilization and decline in lipogenesis (Zemel et al., 2004, 2005).

This randomized clinical trial investigated the effect of an energy-restricted diet containing high protein from dairy products compared to other animal protein sources added to moderate-intensity aerobic exercise on weight and central obesity in the short term. To our knowledge, no study was conducted to assess this question.

2. Method and materials

The trial was an open-label, parallel-group randomized control trial in primary/secondary care. The trial was designed as a pragmatic management assessment in which specific events were expected and permitted. The study received ethical approval from the ethical committee of the Tehran University of Medical Sciences (registration number IRCT20201102049229N1).

A total of sixty eligible participants, 20-45-year-old overweight women, were recruited among people who were referred to the obesity clinic in Sports Medicine Department and interested people who were informed about the research by advertising leaflets which were distributed in the hospital. Finally, all of the participants were randomized into two groups if they met the inclusion criteria (Table 1). The eligible participants were informed about the research process and signed a written consent before inclusion in the trial.

2.1. Randomization

Simple randomization to one of two 700 Kcal restricted high protein diet options, intervention group with high-dairy products and 40 g of casein supplement or high protein low-dairy diet (1:1), was performed by computer-generated sequence allocation using a centrally managed web-based automated system.

2.2. Outcomes

The primary outcomes were a change in abdominal and suprailiac skinfold thickness as indices of central body fat. The secondary outcomes were body weight; BMI; waist and hip circumferences; and Waist to Hip Ratio (WHR).

2.3. Protocol and measurements

Anthropometric measures were collected at the first visit. First, the height, weight, and BMI were measured accurately and recorded. Then, body analysis was performed by the bioimpedance device (BIA) made in South Korea (AVIS33 body composition analyzer, Jawon Medical Co. Ltd, South Korea.) to estimate the amounts of Mean Body Fat (MBF), Percentage Body Fat (PBF), Soft Lean Mass (SLM), Body Mass Index (BMI), Fat Mass (FM) and Fat-Free Mass (FFM). Individuals were instructed to abstain from eating or drinking for 4 h and doing any exercises for 12 h before performing the body analysis. Participants also avoided consuming sub-

Table 1
Inclusion and exclusion criteria.

Inclusion criteria
• Women 20-45-year-old with a BMI of 25–29.9 kg/m^2
• No history of uncontrolled metabolic or cardiorespiratory disease, renal impairment, migraine, or musculoskeletal disorder that impedes the physical activity
• Not taking medications affecting the weight, appetite, or heart rate
• No history of lactase deficiency
• No history of taking supplements in the last three months
• Not pregnant or breastfeeding state
• No significant weight gain or weight loss before the study (A change of more than 10% of body weight in the last six months was considered significant)
• Not using a pacemaker or any other metallic devices
Exclusion criteria
• Pregnancy during the period of the study
• Affecting by any musculoskeletal or neurological disorders preventing regular physical activity
• Starting any medications affecting body weight or/and appetite
• lack of interest in continuing participation in the study

stances that promote diuresis, such as diuretic medication, alcohol, caffeine, and chocolate, before the test. Finally, measurements were performed about 30 min following bladder emptying.

Abdominal and suprailiac skinfolds were measured twice using a standard Slim Guide calliper. The third skinfold measurement was repeated at the same point if there was more than a 1–2 mm discrepancy. Finally, the average of two more similar amounts was recorded as the skinfold measure. Abdominal, waist and hip circumferences were determined with a tape, and the Global Physical Activity Questionnaire (GPAQ) was applied to assess the person's activity level (Mohebi et al., 2019; Kamalian et al., 2021).

Thirty women in the intervention group were on a high protein and calcium diet, including high amounts of dairy products with a 700 Kcal daily energy restriction. The total protein for the daily regimen was 1.5 g/kg of total body weight, supplied mainly by 4–5 units of low-fat milk, each containing about 290 mg of calcium. The rest of the protein requirement was provided by consuming white meat, egg whites, and 40 g of casein powder supplement. Thirty women in the control group followed a 700 Kcal restricted diet, 1.5 g/kg/day of total body weight protein provided by non-dairy animal sources, including meat and egg whites. In addition, one unit of cheese provides 200 mg of calcium, and one serving of low-fat milk containing 290 mg of calcium was considered for the control group's diet. Other food groups, such as fruit, vegetables and fat, were provided in both groups in the accepted calorie range. The dietary program was calculated individually, and one session of face-to-face education was held for each participant. During the study, one researcher was available online in order to answer any questions about the dietary plan or other problems. At first, after one week and at the end of the study, participants completed a 24 h recall to evaluate their adherence to the dietary plan.

Besides the calorie-restricted diets, a moderate-intensity aerobic exercise program was prescribed for both intervention and control groups. Each participant's treadmill-based exercise test determined the appropriate speed and step/min for brisk walking. First, reserved Heart Rate (RHR) was calculated by subtracting the resting heart rate from the maximal heart rate. The formula (220-age) was used to predict the maximal heart rate indirectly. According to the RHR value, the recommended heart rate limits during moderate-intensity exercise were considered between %40 and %60 RHR. Then, the number of steps/minute and the treadmill's speed were identified during the exercise test. Based on the test's result, brisk walking was prescribed with an intensity compatible with the steps number or treadmill's speed in the range of %40–60 of RHR. Recommended duration of the prescribed exercise was 30 min at least three days a week for two weeks, with 5 min of warm-up and cool-down at the beginning and the end of the exercise, respectively. Patients were given a logbook to record their exercise sessions; in addition, they completed the GPAQ questionnaire at the start and end of the study. After two weeks, anthropometric measurements and body analyses were repeated for the 47 remaining participants in total (%78), and thirteen persons (%22 of all participants) left the study. Before and after the trial, all measures were compared to demonstrate the within-group and between-group differences.

2.4. Statistical analysis

Data analysis was performed using SPSS software version 21. Sample size calculations were based on the number of participants needed to have 80% power to test the primary hypothesis. We anticipated that participants in the intervention group would lose, on average, 1 mm or more of abdominal and suprailiac skinfold thicknesses compared to the control group after two weeks. A P-value of less than 0.05 was regarded as significant. The Kolmogorov-Smirnov test was used to check the normality of data distribution. This test showed normal data distribution, so both independent t-tests and paired t-tests were permitted. Paired *t*-test was used to compare the data before and after the intervention and control group. Due to the relatively high rate of dropout (22%), this study applied per-protocol and intention to treat (with the last observation carried forward method) analyses principles for data analysis.

3. Results

In this study, 60 overweight women (BMI between 25 and 29.9) participated, 47 of whom entered the final analysis. Fig. 1 shows the participants' entry process to the study's final measurement.

The initial evaluation of all studied variables was recorded at the first visit. These variables included height, weight, age, BMI, MBF, PBF, SLM, FMI (Fat Mass Index), FFMI (Fat-free mass index), BAI (Body Adiposity Index) and WHR (Waist Hip Ratio). The mean

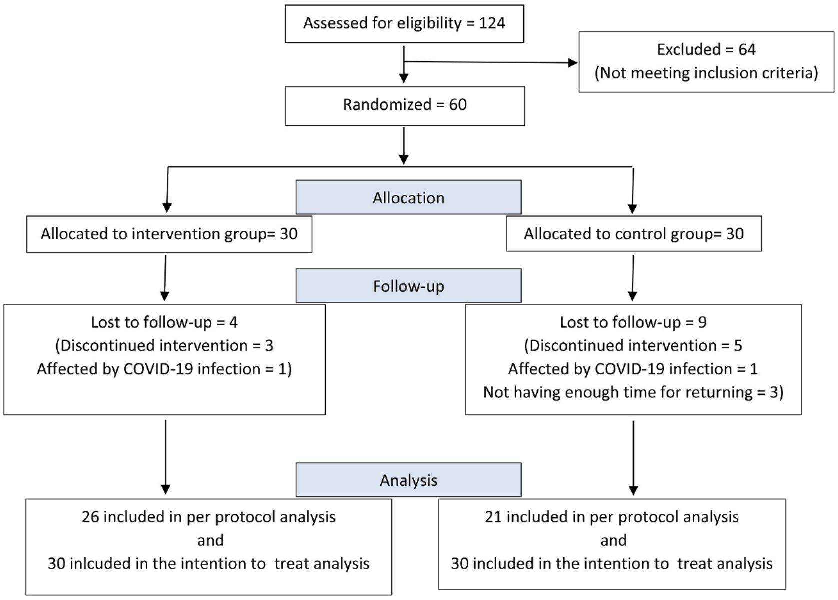

Fig. 1. The trial profile - flowchart demonstrating the participants' recruitment process to the study's final measurement.

height, weight, and age were measured as 160.1 (6.29) cm, 70.3 (6.25) kg, and 37.83 (6.55) years, respectively. Separate comparisons were made between each variable specific to the intervention and control groups. Neither of the variables showed a statistically significant difference, with the exception of the average height, which was noticeably lower in the control group. Baseline characteristics in the two groups are shown in Table 2.

All of the mentioned variables changed significantly in the intervention group after the trial (Table 3 and Supplementary Table 1). While in the control group, changes were not significant for MBF, SLM, FMI, and FFMI variables after two weeks. The data relating to this group are shown in Table 4 (and Supplementary Table 2).

In the between-group comparison of changes, the intervention group's two criteria of central fat (abdominal skinfold and suprailiac) significantly improved compared to the control group. This comparison is shown in Table 5 and Figs. 2 and 3. However, all other changes in the rest of the variables were not significant between the two groups.

Adherence to the exercise during the study was expressed as a percentage. It was calculated as 66.54% and 64.76% in the two groups of intervention and control, respectively. Between groups comparison of adherence showed no statistically meaningful difference (CI95%: 11.2%-14.76%, $P = 0.78$). Also, comparing pre-study activity levels with GPAQ showed no significant difference between the two groups (Table 6).

Table 2
Baseline characteristics of both groups.

Variable	Intervention groupMean (SD)	Control groupMean (SD)	P Value
Weight(kg)	71.34 (7.31)	68.77 (6.08)	0.1
Height (cm)	162.25 (7.17)	157.85 (4.37)	0.01
BMI (kg/m2)	26.97 (1.65)	27.84 (1.79)	0.09
MBF (kg)	25.15 (2.80)	25.00 (3.20)	0.86
PBF (%)	35.28 (1.84)	36.24 (2.21)	0.11
SLM (kg)	42.17 (4.67)	39.90 (3.11)	0.06
FMI (kg/m2)	9.55 (0.98)	10.12 (1.18)	0.08
FFMI (kg/m2)	17.47 (0.73)	17.77 (0.69)	0.35
Waist C (cm)	92.31 (3.90)	92.17 (6.07)	0.95
Hip C(cm)	107.34 (5.02)	105.95 (4.61)	0.3
Abdomen SF (mm)	45.02 (5.82)	47.55 (7.33)	0.22
Suprailiac SF (mm)	39.56 (4.39)	40.62 (6.20)	0.56
BAI	57.19 (3.32)	58.69 (3.87)	0.09
WHR (%)	0.86 (0.05)	0.87 (0.06)	0.51

Statistical difference: $p < 0.05$, BMI: Body Mass Index, MBF: Mean Body Fat, PBF: Percent Body Fat, SLM: Soft Lean Mass, FMI: Fat Mass Index, FFMI: Fat-Free Mass Index, Waist C: Waist Circumference, Hip C: Hip Circumference, Abdomen SF: Abdominal Skinfold, Suprailiac SF: Suprailiac Skinfold, BAI: Body Adiposity Index, WHR: Waist Hip Ratio, SD: Standard Deviation.

Table 3
Baseline and changes in anthropometric measurements in the intervention group.

Variable	Baseline Mean (SD)	After study Mean (SD)	Change	Confidence interval	P Value (Per Protocol)
Weight(kg)	71.34 (7.31)	69.76 (7.35)	1.58	1.17–1.99	0.000
BMI (kg/m^2)	26.97 (1.65)	26.41 (1.60)	0.55	0.37–0.74	0.000
MBF (kg)	25.15 (2.80)	24.16 (3.09)	1	0.59–1.41	0.000
PBF (%)	35.28 (1.84)	34.61 (2.32)	0.68	0.18–1.18	0.010
SLM (kg)	42.17 (4.67)	41.69 (4.61)	0.47	0.12–0.82	0.010
FMI (kg/m^2)	9.55 (0.98)	9.17 (1.09)	0.38	0.23–0.53	0.000
FFMI (kg/m^2)	17.47 (0.73)	17.26 (0.66)	0.21	0.07–0.36	0.005
Waist C (cm)	92.31 (3.90)	88.80 (4.58)	3.46	2.65–4.27	0.000
Hip C (cm)	107.34 (5.02)	104.91 (4.71)	2.56	1.99–3.13	0.000
Abdomen SF (mm)	45.02 (5.82)	40.32 (5.29)	4.82	3.73–5.91	0.000
Suprailiac SF (mm)	39.56 (4.39)	36.48 (4.26)	0.22	2.26–4.18	0.000
BAI	57.19 (3.32)	54.78 (3.29)	2.41	1.64–2.64	0.000

Intervention group: 26 included in per protocol analysis and 30 included in the intention to treat analysis; Control group: 21 included in per protocol analysis and 30 included in the intention to treat analysis.
Statistical difference: $p < 0.05$, BMI: Body Mass Index, MBF: Mean Body Fat, PBF: Percent Body Fat, SLM: Soft Lean Mass, FMI: Fat Mass Index, FFMI: Fat-Free Mass Index, Waist C: Waist Circumference, Hip C: Hip Circumference, Abdomen SF: Abdominal Skinfold, Suprailiac SF: Suprailiac Skinfold, BAI: Body Adiposity Index, SD: Standard Deviation.

Table 4
Baseline and changes in anthropometric measurements in the control group.

Variable	Baseline Mean (SD)	After study Mean (SD)	Change	Confidence interval	P-Value (Per Protocol)
Weight(kg)	68.77 (6.08)	67.23 (5.69)	1.54	1.05–2.02	0.000
BMI (kg/m^2)	27.84 (1.79)	27.22 (1.70)	0.62	0.43–0.81	0.000
MBF (kg)	25.00 (3.20)	24.81 (5.78)	0.19	−1.81- 2.19	0.844
PBF (%)	36.24 (2.21)	35.27 (2.52)	0.97	0.32–1.61	0.005
SLM (kg)	39.90 (3.11)	39.65 (2.74)	0.25	−0.06-0.56	0.110
FMI (kg/m^2)	10.12 (1.18)	10.06 (2.42)	0.06	−0.78-0.90	0.879
FFMI (kg/m^2)	17.77 (0.69)	17.59 (0.62)	0.18	−0.00-0.37	0.055
Waist C (cm)	92.17 (6.07)	89.24 (6.54)	2.93	2.27–3.58	0.000
Hip C (cm)	105.95 (4.61)	103.90 (4.63)	2.05	1.49–2.60	0.000
Abdomen SF (mm)	47.55 (7.33)	44.71 (7.05)	2.84	1.76–3.91	0.000
Suprailiac SF (mm)	40.62 (6.20)	38.62 (5.66)	2	1.38–2.61	0.000
BAI	58.69 (3.87)	56.83 (4.15)	1.86	1.45–2.28	0.000

Intervention group: 26 included in per protocol analysis and 30 included in the intention to treat analysis; Control group: 21 included in per protocol analysis and 30 included in the intention to treat analysis.
Statistical difference: $p < 0.05$, BMI: Body Mass Index, MBF: Mass Body Fat, PBF: Percent Body Fat, SLM: Soft Lean Mass, FMI: Fat Mass Index, FFMI: Fat-Free Mass Index, Waist C: Waist Circumference, Hip C: Hip Circumference, Abdomen SF: Abdominal Skinfold, Suprailiac SF: Suprailiac Skinfold, BAI: Body Adiposity Index, SD: Standard Deviation.

4. Discussion

The results of our study indicate that a high-protein and high-calcium diet, mainly supplied from dairy products and supplemented by 40 g of casein daily, leads to a more significant reduction of central fat in comparison to a regimen of high-protein and low calcium in overweight women when these diets were added to restricted energy intake and moderate-intensity aerobic exercise. After two weeks, weight loss was seen in both intervention and control groups. All the studied variables, including weight, MBF, PBF, SLM, BMI, FM, FFM, BAI, abdominal and supra-iliac skinfolds measures and WHR in the intervention group were considerably changed after the study. This statistical significance was observed in all findings of the control group except for the variables of MBF, SLM, FM, and FFM. In addition, between-group analysis showed more changes in skinfold measurements in the intervention group. Therefore, when combined with a high-calcium diet, a high-protein diet has a better effect on lowering the variables and markers related to body fat than a low-calcium diet.

In 2005, Melanson et al. conducted a randomized crossover study to compare the impact of a low-dairy diet, consuming approximately one serving per day (roughly 500 mg of calcium), with a high-dairy diet, consumption of about three to four servings per day (almost 1400 mg of calcium), on oxidation of macronutrients. Each group was subjected to one of these diets for a week, and each diet was repeated two times. On the seventh day of each episode, individuals were examined under the condition of energy balance and acute energy deficits in a calorimeter room. An energy deficit of about 600 kcal per day was induced for only 24 h when the participants were in the calorimeter room. This condition was induced by a combination of exercise and calorie restriction. The results showed that diet therapy had no significant effect on respiratory rate and 24-h macronutrient oxidation in the state of energy balance. In contrast, energy deficiency conditions caused a considerable increase in 24-h fat oxidation on the high-dairy diet (Melanson et al., 2005). Our study did not show a significant difference in fat reduction between the two groups; however, central fat as an index of total body fat was decreased significantly in the group under a calcium-rich diet.

Table 5
Comparison of anthropometric changes between intervention and control groups.

Variable	Intervention Mean (SD)	Control Mean (SD)	CI of change (Per Protocol)	P-Value (Per Protocol)	CI of change (Intention to Treat)	P-Value (Intention to Treat)
Weight (kg)	−1.58 (1.01)	−1.53 (1.06)	−0.57-0.65	0.886	−0.28-0.87	0.311
BMI (kg/m²)	−0.55 (0.47)	−0.62 (0.42)	−0.33-0.19	0.595	−0.2-0.28	0.718
MBF (kg)	−1.00 (1.02)	−0.19 (4.39)	−0.98-2.59	0.368	−0.65-2.11	0.295
PBF (%)	−0.68 (1.24)	−0.97 (1.42)	−1.07-0.49	0.460	−0.72-0.54	0.776
SLM (kg)	−0.47 (0.87)	−0.25 (0.68)	−0.24-0.69	0.335	−0.13-0.6	0.201
FMI (kg/m²)	−0.38 (0.38)	−0.06 (1.84)	−0.43-1.06	0.396	−0.29-0.86	0.326
FFMI (kg/m²)	−0.18 (0.34)	−0.09 (0.26)	−0.09-0.27	0.328	−0.05-0.23	0.198
Waist C (cm)	−3.46 (1.95)	−2.93 (1.43)	−0.50-1.57	0.305	−0.11-1.98	0.115
Hip C (cm)	−2.56 (1.37)	−2.05 (1.21)	−0.26-1.29	0.191	0.01–1.54	0.074
Abdomen SF (mm)	−4.82 (2.63)	−2.83 (2.36)	0.49–3.48	0.011	0.77–3.57	0.005
Suprailiac SF (mm)	−3.22 (2.32)	−2.00 (1.35)	0.06–2.38	0.040	0.32–2.43	0.017
BAI	−2.14 (1.21)	−1.87 (0.91)	−0.37-0.92	0.400	−0.12-1.19	0.150
WHR (%)	−0.01 (0.01)	−0.01 (0.01)	−0.01-0.01	0.765	−0.01-0.01	0.765

Intervention group: 26 included in per protocol analysis and 30 included in the intention to treat analysis; Control group: 21 included in per protocol analysis and 30 included in the intention to treat analysis.
Statistical difference: $p < 0.05$, BMI: Body Mass Index, MBF: Mass Body Fat, PBF: Percent Body Fat, SLM: Soft Lean Mass, FMI: Fat Mass Index, FFMI: Fat-Free Mass Index, Waist C: Waist Circumference, Hip C: Hip Circumference, Abdomen SF: Abdominal Skinfold, Suprailiac SF: Suprailiac Skinfold, BAI: Body Adiposity Index, WHR: Waist Hip Ratio, SD: Standard Deviation.

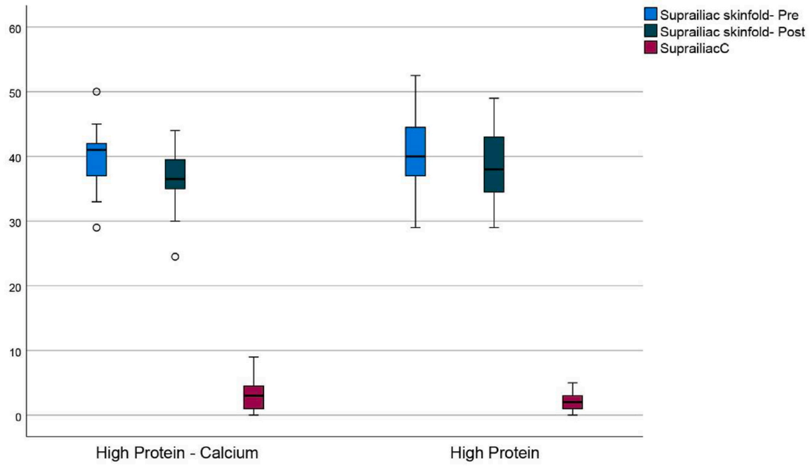

Fig. 2. Suprailiac skin fold thickness at baseline (blue) and after two weeks of intervention (green), and their changes throughout the study (red) in both groups. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Another study, done by Jacobsen et al., in 2005, aimed to examine the effect of high and low calcium intake, mostly from low-fat dairy products, in diets containing normal or high protein, on daily energy expenditure (EE) and oxidation of the substrate, faecal energy, and excretion of the fat, in addition to substrates and hormones shares in energy metabolism and appetite. A total of 10 patients in a randomized crossover study underwent three isocaloric 1-week diets, including low calcium and normal protein (a diet containing 500 mg calcium and 15% protein), high calcium and normal protein (a diet containing 1800 mg calcium and 15% protein), and high in both calcium and protein (a diet containing 1800 mg calcium and 23% protein). Although calcium intake did not affect 24-h EE or fat oxidation, the faecal fat and energy excretion were elevated when people were under a diet of high calcium and normal protein compared to the other two diets. None of the three diets affected the hormones involved in energy metabolism and appetites. According to this study, a short-term increase in calcium and natural protein intake might be a practical approach to increasing the daily excretion of fat and faecal energy. In other words, they showed that a high-calcium diet could cause weight loss. The authors also highlighted the importance of dietary protein in energy consumption and weight loss. Therefore, it seems that one mechanism to reduce body weight and body fat in a high-dairy diet could be an increase in fat excretion. While we found a more fat reduction in the trial group compared to the control group (1 kg vs 0.19 kg), the changes were insignificant between groups. However, central fat decreased significantly in the trial group; adding exercise to our method could be one of the potentially effective causes of removing more central fat. (Jacobsen et al., 2005).

In a 2007 study by Lorenzen et al., 18 men with a body mass index of 24–31 were selected. The researchers aimed to investigate the effect of high calcium intake from dairy sources or supplements on appetite and postprandial fat metabolism via fat malabsorption. In a randomized crossover study, four different meals with equal calories were served to 18 participants. These servings were

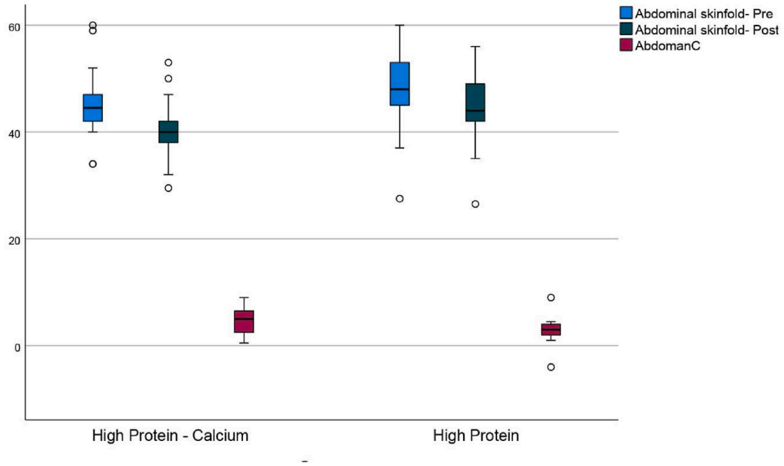

Fig. 3. Abdominal skin fold thickness at baseline (blue) and after two weeks of intervention (green), and their changes throughout the study (red) in both groups. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 6
Comparison of physical activity level at baseline between intervention and control groups.

Variable	Intervention Mean (SD)	Control Mean (SD)	P-Value (Per Protocol)	Confidence interval	P-Value (Intention to Treat)
PA (min)	561.54 (315.43)	681.54 (676.83)	0.568	−547.44-307.44	0.166
P16A (hour)	9.54 (2.39)	10.10 (3.35)	0.512	−2.25-1.14	0.641

Statistical difference: $p < 0.05$, PA: physical activity per day, P16A: physical inactivity during the day, including sitting and resting time, and excluding sleeping time (item 16 in GPAQ questionnaire), SD: Standard Deviation.

categorized into three types based on the calcium content high (172 mg), medium (84 mg), low (15 mg), and the fourth contained high calcium (183 mg), provided by a calcium carbonate supplement. Dairy calcium's postprandial lipid response was shown to be considerably declined, while this effect was not observed for calcium carbonate supplementation. In other words, this study showed that increasing calcium intake might reduce postprandial blood lipids due to decreased fat absorption. Still, it was restricted to receiving calcium from dairy products. The chemical form of calcium or cofactors in dairy products might be the reason why calcium supplementation did not have the same effect. Appetite feeling, glucose metabolism, or intestinal hormone secretion showed no significant change in this study (Lorenzen et al., 2007). As Lorenzen et al. reported, in the present study, we benefited from calcium plus high protein in dairy products to reduce body fat.

A meta-analysis conducted in 2011 by Abarqawi et al. examined the effect of dairy consumption on weight and body composition in adults and found that a diet with increased dairy products, accompanied by limited energy intake, had a significant impact on weight loss. Body fat, waist circumference, and weight loss would be comparable to conventional weight-loss diets (Abargouei et al., 2012). The interesting point of this review study, which we also observed in our research, was the secret of combining dietary calorie restriction with dairy products to benefit from its effect on body weight and composition in addition to the impact on increasing LBM. Overall, the results of the present study can confirm the effect of high-protein diets on weight loss and relevant body indices since both groups in our study experienced significant weight loss. However, a high-protein, high-calcium diet caused significant changes in body fat-related variables and indices. Therefore, it can be deduced that high-protein, high-calcium diets, like a regimen containing large amounts of milk and dairy products, could be good choices because not only do these diets eliminate or reduce the consumption of red meat, but they are also healthier diets and can be appropriate alternatives for the ones which only contain animal protein (van den Brandt, 2019).

Regarding the impact of high calcium and protein diet on body fat indices, including waist and hip circumferences and body fat, before and after the trial, we found a significant improvement in all variables compared to the baseline data in the intervention group, while the control group showed no improvement in MBF, SLM, FM, FFM. Moreover, changes in abdominal and suprailiac skinfolds were measured in the present study to evaluate the amount of central body fat, which showed considerable changes in the intervention group compared to the control group ($p = 0.01$ and $p = 0.04$, respectively). Both of our groups received a low-calorie diet and aerobic exercise, so we expected that both groups decrease weight and fat mass. In other words, finding a difference between two effective protocols is difficult. Based on our hypothesis and according to some evidence calcium-reach diet has a better effect on central fat reduction (Zemel et al., 2005). Since skinfold changes are greater than visceral fat changes in the human body (Merlotti et al., 2017), so we found skinfold changes more significant in the intervention group. In addition, we detected more changes in other fat variables, but insignificant in the intervention group, such as MBF (−1.00 ± 1.02 Vs −0.19 ± 4.39), so if we continue the diary protocol for a more extended period, we could probably make more significant changes in other fat indices.

Comparing the duration of the interventions, similar studies in this field were often conducted over much more extended periods. For instance, a 2011 study by José et al. on 90 women between the ages of 19 and 45 (before menopause) lasted 16 weeks, in which participants were randomly divided into three groups and, while performing daily aerobic or resistance exercise, received low-energy diets containing various protein compounds from dairy products along with calcium. These diets included high protein + high dairy (HPHD), sufficient protein + medium dairy (APMD), and adequate protein + low dairy (APLD). The results showed that despite weight loss in all three groups, fat loss and increase in muscle mass during the 8th −16th weeks occurred more in the HPHD group than in the APMD and APLD groups ($P < 0.05$). In addition, the reduction of visceral fat in all groups was associated with both calcium ($r = 0.40$; $P < 0.05$) and protein ($r = 0.32$; $P < 0.05$) consumption (Josse et al., 2011). Therefore, despite the dissimilarity of study duration, their study showed the same results as our study in terms of weight loss when people exercise plus take a high protein diet consisting of increased consumption of dairy products. On top of that, this measure led to more favourable body composition changes and further reduced total and visceral fat in women.

A meta-analysis conducted by Chen et al., in 2012 examined the impact of time on dairy diets, and a total of 29 RCTs with 2101 participants were reviewed. In the subgroup analysis, consumption of dairy products in short-term interventions (less than one year) or those with energy restriction significantly reduced body weight and body fat, but in long-term interventions (more than one year), the results showed the opposite effect. In other words, based on this meta-analysis, the literature does not support the advantageous effect of increasing dairy consumption on weight loss and lowering body fat in the long run or the absence of energy constraints. Nonetheless, dairy products might have moderate benefits in facilitating weight loss in short-term trials or when these diets are accompanied by energy restriction (Chen et al., 2012). Therefore, declining the central fat, which was confirmed by reducing the amount of abdominal and suprailiac skinfolds in our study, achieved by a diet high in both calcium and protein along with calorie restriction and short-term moderate aerobic exercise, was in line with the results of this meta-analysis.

In conclusion, based on the findings of the current study and comparisons with previous research in this field, diets containing protein from dairy products with high calcium intake are more effective than typical diets that merely contain high protein from animal sources without high calcium intake in terms of weight loss and the reduction of indices related to body fat. For overweight women, in particular, short-term use of high calcium and protein diets derived from dairy sources is advised, with calorie restriction and moderate-intensity cardiovascular activity.

4.1. Limitations of the study

There are several limitations to this study. This study was restricted to female subjects only due to metabolic rate differences leading to potential biases; Future research should focus on a broader population and include both sexes and wider age groups. Additionally, there were only a small number of participants; thus, this may need to be addressed in future research, especially when different age groups are included to account for greater variability. Another serious barrier to using the findings as a primary preventive method is the short trial duration, especially in light of the importance of sustainability and long-term effects in the primary prevention of obesity. Another limitation of the study was prescribing a high dairy-high protein diet based on low-fat milk and casein supplement, so it cannot entirely be determined whether a high dairy diet where all dairy protein sources come from whole foods would have the same results. Since muscle mass was significantly reduced in the intervention group of the present study, augmenting the design by strengthening exercises to maintain and increase SLM and FFM is suggested for future studies.

Although exercise self-reported records are convenient, potential attrition to exercise and supervision poses additional serious issues in interpreting this complex intervention. Finally, the exact amounts of macronutrients and calorie intake were not revealed by a 24-h recall.

5. Conclusion

This study aimed to investigate and compare the effect of two high-protein diets (one higher in calcium) on losing weight and central fat in overweight women. Both diets involved carefully monitored, limited energy intake and were supplemented by tailored aerobic activity advice. The study results showed that the group that consumed a diet containing dairy products (high calcium) benefited more because of a more significant reduction in indices related to central fat. Therefore, a high-protein diet which is high in calcium (milk and dairy products) at the same time can be considered a top priority compared to other diets due to its more significant effect on abdominal fat reduction.

CRediT authorship contribution statement

Zahra Bodaghabadi: carried out the research. **Leyla Ostad Mohammadi:** carried out the research. **Farzin Halabchi:** analyzed data, Data curation, Formal analysis. **Zahra Tavakol:** wrote the first version of the manuscript. **Stefan Kluzek:** reviewed and finalized the manuscript, Writing – review & editing. **Mastaneh Rajabian Tabesh:** carried out the research. **Maryam Abolhasani:** wrote the first version of the manuscript. **Zahra Alizadeh:** designed the study, reviewed and finalized the manuscript, Writing – review & editing.

Declaration of competing interest

Financial disclosure statements have been obtained, and no conflicts of interest have been reported by the authors. Authors whose names appear on the submission have contributed sufficiently to the scientific work and therefore share collective responsibility and accountability for the results.

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designed the study; Zahra Bodaghabadi, Leyla Ostad Mohammadi and Mastaneh Rajabian Tabesh carried out the research; Farzin Halabchi analyzed data; Zahra Tavakol and Maryam Abolhasani wrote the first version of the manuscript; and finally, Zahra Alizadeh and Stefan Kluzek reviewed and finalized the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.obmed.2023.100492.

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