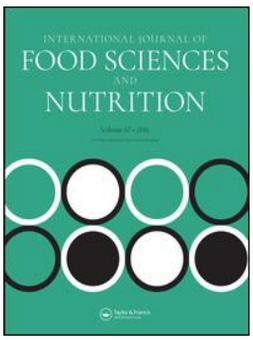

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RESEARCH ARTICLE

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The effect of canola, sesame and sesame-canola oils on body fat and composition in adults: a triple-blind, three-way randomised cross-over clinical trial

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ABSTRACT

The present study aimed to examine the effect of replacing edible oils with sesame oil (SO), canola oil (CO) and sesame-canola oil (SCO) on body weight and composition in adults. Adults without any chronic diseases ($n = 77$) were entered a 4-week run-in period and then were randomised to receive SO, CO and SCO for their household use in 9-week intervention periods (separated by 4-week washout intervals). Anthropometric measurements, as well as body composition markers, were assessed at baseline, middle and after each intervention period. In total, 73 participants completed the study. Although significant time effects were seen for waist and hip circumference, waist-to-hip ratio, central obesity index, body adiposity index, muscle mass and body fat percent ($p_{time} < .05$), the treatment and treatment × time effects were not significant ($p > .05$). The present clinical trial revealed that CO, SO and SCO might not differently affect body fat and composition. Trial registration code: IRCT20160913125571N6 (http://en.irct.ir/trial/12622).

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Dietary oils; sesame oil; canola oil; obesity; body weight; body composition

Introduction

Obesity, characterised by excessive accumulation of fat, is now a global concern which has been escalating more rapidly over the recent years (Barzin et al. 2015; Flegal et al. 2016). The World Health Organization (WHO), in 2016, reported that 13% of adults aged 18 years and older are threatened with obesity. It is also reported that the prevalence of obesity has been nearly tripled from 1975 (Margetts and Nelson 1997). Obesity increases the possibility of several chronic diseases such as type 2 diabetes mellitus (T2DM), cardiovascular diseases (CVDs), hypertension and certain cancers (Haslam and James 2005; Ramachandran and Snehalatha 2010); therefore, it causes substantial economic burden on health care systems (Yu et al. 2007; Tsai et al. 2011). Lifestyle change including physical activity and diet are needed to manage weight in subjects with overweight and obesity (Chan et al. 2013). Due to the high content of energy in dietary fat, there is a prevalent belief that reducing fat intake might lead to weight loss (Hill et al. 2012). However, it is suggested that adherence to a low-fat diet over a long time for weight loss is not generally acceptable (McManus et al. 2001). Current recommendations accentuate the energy intake and the quality of the dietary fat rather than its quantity (Erkkila et al. 2008). Several studies have revealed that omega-3 poly-unsaturated fatty acids (PUFAs) might promote weight loss (Krebs et al. 2006; Scaglioni et al. 2006; Micallef et al. 2009). In addition, it is proposed that omega-3 PUFAs affect the postprandial satiety during weight loss in subjects with obesity and overweight (Parra et al. 2008).

Canola oil (CO) is one of the most commonly consumed vegetable oils around the world and the replacement of regular dietary oils with this oil is increasing. It is regarded as a favourable oil due to its appropriate fatty acid content. It contains alpha-linolenic acid (ALA) (about 11%), an essential omega-3 fatty acid, which is the precursor of long chain omega-3 fatty acids namely eicosapentaenoic acid

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(EPA) and docosahexaenoic acid (DHA) (Johnson et al. 2007; Dittrich et al. 2015). Although its conversion is not very efficient in the human body, but it is indicated that using ALA-rich vegetable oils elevates EPA concentrations in body tissues (Mantzioris et al. 1994; Gerster 1998). Furthermore, CO contains linoleic acid (21%), mono-unsaturated fatty acids (MUFAs) as oleic acid (61%), and only 7% of saturated fatty acids (SFA) (Johnson et al. 2007; Gunstone 2011). On the other hand, sesame oil (SO) is another edible oil which is widely consumed in Asian countries (Namiki 2007) and is proposed to have favourable effects on blood pressure, lipid profiles and body adiposity indices (Khalesi et al. 2016; Khosravi-Boroujeni et al. 2017; Raeisi-Dehkordi et al. 2018). Sesame oil has high nutritional value due to the high amounts of lignans, phytosterols, tocopherol and unsaturated fatty acids (like linoleic acid) content (Kang et al. 1999; Sukumar et al. 2008; Pathak et al. 2014). It is suggested that sesamin, as an important lignan, has anti-obesity and anti-oxidant effects (Nakano et al. 2008; Yuliana et al. 2011). Additionally, SO has a high amount of vitamin E (40 mg/100 g oil) as an antioxidant (Sankar et al. 2006b). A limited number of studies have considered the effect of CO and SO on body weight and fat. It is proposed that the consumption of CO is associated with a reduced fat mass (Liu et al. 2016). A recent systematic review and meta-analysis have revealed that sesame consumption might affect body fat percent and body adiposity index (BAI), although the effect was not significant for body weight and body mass index (BMI) (Raeisi-Dehkordi et al. 2018).

To the best of our knowledge, no study has investigated the effect of CO compared to SO on body weight and composition. Since both CO and SO are recognised as healthy, the current study tried to compare the effects of SO, CO and sesame-canola oil (SCO: a blend of these two edible oils) on the anthropometric indices in adults.

Methods

The study design and participants

The current study is derived from a parent triple-blind, randomised, three-way cross-over clinical trial that was conducted on adults with T2DM and their spouses with the aim of examining the effects of replacing household dietary oils with SO, CO and SCO on cardiometabolic risk factors. The exact information on the study protocol and participants' characteristics has been explained elsewhere (Amiri et al. 2019). Written informed consents were obtained from all participants prior to the start of the study and the study was registered in the Iranian Registry of Clinical Trials (IRCT) on 14 November 2016 with registration number of IRCT2016091312571N6. Ethical approval codes were obtained from the Ethics Committee of Shahid Sadoughi University of Medical Sciences; Yazd, Iran for the parent study (Amiri et al. 2019). The ethical committee also reviewed and approved the current study on 20 December 2017 (IR.SSU.SPH.REC.1396.142).

In the present study, we aimed to examine the effects of intervention oils on adiposity markers in healthy adults. Therefore, the spouses with the following criteria were selected from the parent study: (1) those without T2DM (with fasting blood sugar less than 126 mg/dl), (2) aged 18 or older and (3) did not have any history of other chronic diseases including CVDs, kidney or liver diseases (serum glutamic oxaloacetic transaminase (SGOT) and serum glutamic pyruvic transaminase (SGPT) three times more than normal values) and cancers. Also, the participants who suddenly changed their dietary habits, experienced chronic diseases such as T2DM, CVDs, cancer or experienced pregnancy during the study period, and did not intend to continue the study with any reason were excluded from the analysis.

Intervention

After 4 weeks of run-in period in which the regular oil was substituted with sunflower oil, eligible participants were randomly allocated to one of the six rolling methods (the randomisation was conducted at family level) to receive the three plant oils namely SO, CO and SCO (be made up of 40% SO and 60% CO) in three phases (Supplementary Figure 1). Three intervention periods lasted for 9 weeks separated by 4-week washout intervals (sunflower oil was provided during washout periods). The intervention oils were provided for each family (adults with type 2 diabetes and their spouses) by investigators during the study. The treatment oils were packed in the same bottle and labelled with three codes (S, B and G) by a person outside the study and not aware of the study objectives. Therefore, the participants, personnel and statisticians were blinded to the intervention oils until after analysis. Gas chromatography with flame ioniser detector ((GC-FID) (Youngling, model: YL6500 GC)) was used to determine the fatty acid profile of the treatment oils (Amiri et al. 2019).

Anthropometric measurements

All the measurements were done in similar situation for all the participants. The anthropometric measurements were performed while participants were in light clothes and no shoes and after 10–15 minutes rest. Furthermore, the participants were asked to remove their jewellery. The anthropometric assessments were done in the morning after an overnight fast. For all the three phases of the experiment, body weight and body composition including waist circumference (WC), hip circumference (HC), visceral fat, total body fat and muscle mass were exactly measured at the start, middle and the end of each intervention phase, by a trained nutritionist. We assessed all anthropometric measurements three times in each visit and their mean value were considered as the final value. The individuals were weighed with minimum clothes and without shoes using a digital calibrated scale (Omron, mode: BF511) to the nearest 100 g. A non-stretchable measuring tape was used to measure waist and HCs to the nearest 1 cm based on standard methods (Wang et al. 2003). Height was accurately measured by using a measuring tape which was fixed on the wall. Visceral fat, total body fat and muscle mass were measured using a bioimpedance analyser (Omron, mode: BF511). Body mass index was calculated by dividing weight (kg) by height squared (m^2). The WC divided by HC to compute waist to hip ratio (WHR). To calculate the index of central obesity (ICO), the WC was divided by height (Parikh et al. 2009), and the BAI was calculated using the equation as follow: $BAI = [(HC)/(height)^{1.5}) - 18]$ (Bergman et al. 2011).

Dietary and physical activity assessments

Although all included participants were advised to follow a weight maintaining diet and keep their regular physical activity (Amiri et al. 2019), the individuals were instructed to accurately fill three-day weighted food intake and physical records (two weekdays and one weekend day) for evaluating their dietary intake and physical activity at the start, middle and the end of the treatment periods. Therefore, a total of nine three-day food and physical activity records were collected for each participant during the study. Additionally, a three-day cooking forms were completed by individuals. Indeed, the participants were provided with a digital kitchen scale (model: Electronic kitchen scale, SF-400) for weighing each ingredient of cooked foods and recording them in that form. Dietary food intakes were calculated using a computer-based program, Nutritionist IV software (version 3.5.2, Axxya Systems, Redmond, WA) which is modified for Iranian foods. The updated version of the compendium of physical activities was used for converting physical activity data to metabolic equivalent-min/day (Ainsworth et al. 2000).

Treatment compliance

The compliance with intervention protocol was evaluated by three-day food records through assessing the consumed oil by each participant and by asking the participants to bring back the oil not used in each study phase. The bottles were weighed before and after each phase by the investigators (Amiri et al. 2019).

Statistical analysis

The normal distribution of outcome variables was checked using the Kolmogorov–Smirnov test. The linear mixed model with Bonferroni's correction considering treatment, time, gender and the rolling method as factors was incorporated to compare the effect of treatment periods (SO, CO and SCO) on adiposity markers in crude and multi-variable adjusted models. Participants' age, BMI, the calculated intervention oils consumed per subject, physical activity level and the energy intake in each intervention period were considered as covariates. The analyses were also conducted based on participants' sex to show the possible specific effects in male and female subjects. The results are reported as means ± standard errors (SEs). All analyses were conducted using IBM SPSS (version 20; IBM Corporation, Armonk, NY). p Values equal or less than .05 were considered as statistically significant.

Results

The flow diagram of participants' enrolment in the current study is provided in Figure 1. Of 77 spouses who met the inclusion criteria and entered to the current study, three participants were dropped out during the course of intervention due to unwillingness to continue. Additionally, one participant was excluded from the statistical analysis owing to a lack of compliance based on dietary food records. Furthermore, 3 and 4 individuals did not participate at least in one visit during SO and CO intervention periods, respectively. Therefore, 70, 73 and 69 individuals completed SO, SCO and CO periods, respectively (Figure 1). The baseline characteristics of the 73 participants who

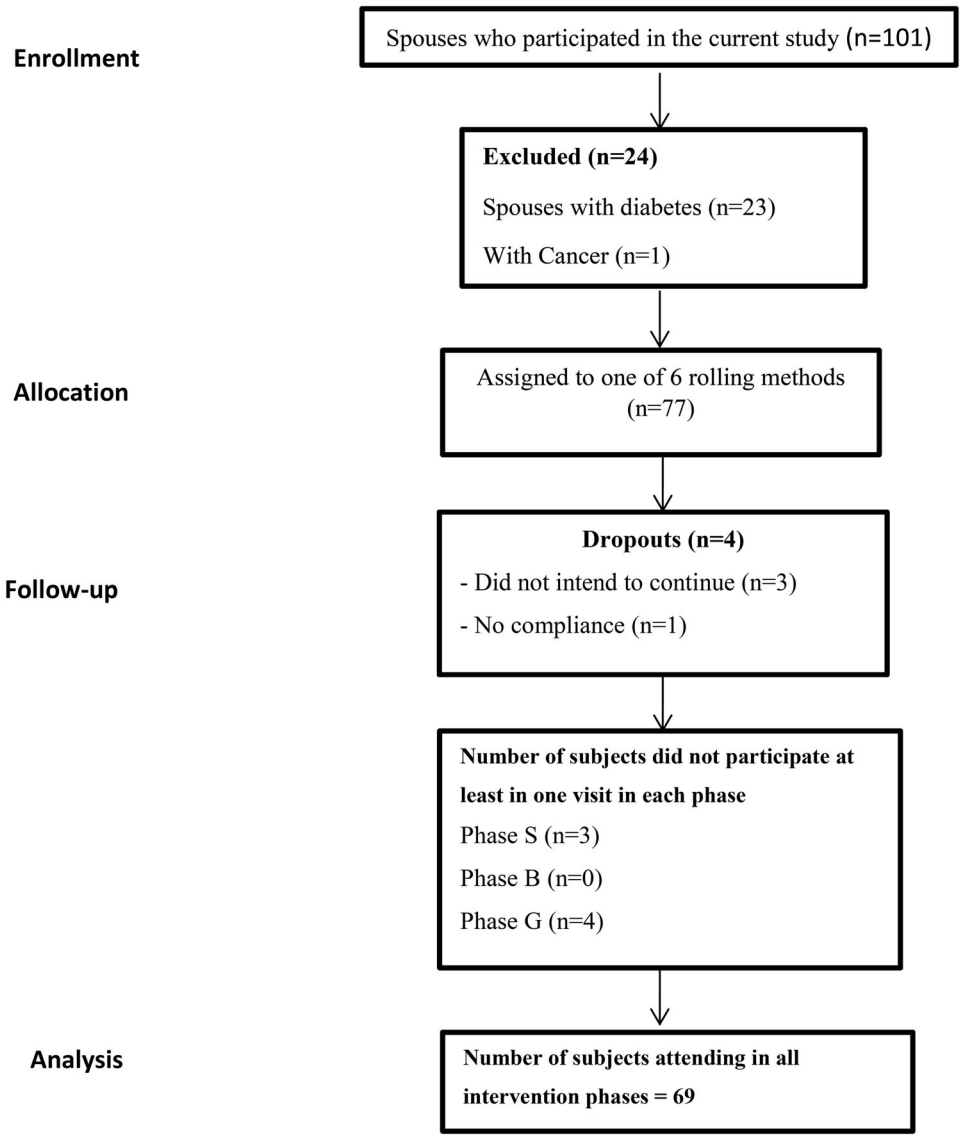

Figure 1. Flow of participants throughout the study.

completed at least one study phase are provided in Table 1.

The participants consumed about 30.09 ± 15.92 g/day of intervention oils. No difference was observed between the intervention periods regarding the amount of ingested oils (p=.58). The analyses revealed that there was no significant difference between the three intervention periods with respect to energy intake (p>.05). The analysis of dietary food records indicated that participants had good compliance with the treatment protocol. Indeed, the mean intake of MUFAs was highest in individuals on the CO (19.63 ± 0.59), followed by SCO (18.28 ± 0.60) and SO (17.71 ± 0.59) treatments (p=.005). Additionally, the PUFAs intake was also significantly different between the three intervention periods (p=.02). No other differences were found between the intervention periods (p>.05). Furthermore, no significant difference was found in physical activity between the three intervention periods (p>.05) (Supplementary Table 1).

The effects of intervention oils on the anthropometric parameters

The crude and adjusted mean ± SE of body weight and composition for after intervention and change in the three intervention periods in all study completers are summarised in Table 2. Data for muscle mass, HC and BAI are provided for the first phase because carry over effect was seen for these markers. After adjustment for confounders including participants' age, BMI, the calculated intervention oils consumed per subject, physical activity and the energy intake in each intervention period, all treatment periods led to a

significant decrease in muscle mass, WC, HC, WHR, ICO and BAI ($p_{time}<.05$, Table 2). Whereas, the body fat was significantly increased during the study periods ($p_{time}=.004$). However, the treatment, treatment × time effects were significant for none of anthropometric parameters ($p>.05$). We found a marginal treatment × gender effect on muscle mass (Table 2, $p<.01$).

In separate analysis based on gender, although the significant time effects mentioned above were seen in females ($p_{time}<.05$, Table 3), no time effect was found in male participants except for muscle mass, WC and ICO ($p_{time}<.05$, Table 4). No significant treatment and treatment × time effect was observed either in males or females (Tables 3 and 4).

The adjusted baseline, middle and after intervention values for body weight and composition indicators are provided in Supplementary Figures 2–4. No difference was seen between the intervention oils.

Table 1. Baseline characteristics of the study participants[a].

Variables	Males ($n=32$)	Females ($n=41$)	Total ($n=73$)
Age (years)	54.09 ± 1.66[b]	42.24 ± 1.08	47.43 ± 1.17
Body weight (kg)	78.40 ± 2.57	72.67 ± 1.51	75.18 ± 1.44
BMI (kg/m^2)	26.99 ± 0.78	29.16 ± 0.72	28.21 ± 0.54
Visceral fat (%)	11.03 ± 0.71	8 ± 0.34	9.28 ± 0.40
Body fat (%)	22.95 ± 1.06	41.69 ± 0.85	33.77 ± 1.28
Muscle mass (%)	35.32 ± 0.52	25.12 ± 0.33	29.43 ± 0.66
WC (cm)	99.12 ± 2	99.02 ± 1.53	99.06 ± 1.22
HC (cm)	102.10 ± 1.23	109.12 ± 1.33	106.04 ± 1
WHR	0.96 ± 0.01	0.90 ± 0.008	0.93 ± 0.007
ICO	0.58 ± 0.01	0.62 ± 0.01	0.60 ± 0.008
BAI	27.99 ± 0.49	37.07 ± 1	33.09 ± 0.80
Education			
Elementary or lower	15.6%	19.5%	17.8%
High school	56.3%	58.5%	57.5%
College and university	28.1%	22%	24.7%

[a]BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist to hip ratio; ICO: index of central obesity; BAI: body adiposity index.
[b]Values are expressed as means ± standard error (SE), otherwise indicated.

Discussion

Sesame and CO are known as healthy oil due to their nutritional components and are recommended for a

Table 2. After and change values for body weight and composition measurements based on the intervention periods in the total participants[a].

	Sesame oil ($n=70$)		Sesame-canola oil ($n=73$)		Canola oil ($n=69$)					
	After	Change	After	Change	After	Change	p^b	p^c	p^d	p^e
Body weight (kg)										
Crude	75.42 ± 1.39[f]	0.09 ± 0.17	75.01 ± 1.45	−0.22 ± 0.46	75.30 ± 1.40	0.17 ± 0.15	.99	.51	.53	.19
Adjusted[g]	75.34 ± 1.46	0.07 ± 0.18	74.95 ± 1.52	−0.21 ± 0.49	75.22 ± 1.46	0.08 ± 0.15	.78	.48	.61	.28
BMI (kg/m^2)										
Crude	28.31 ± 0.55	0.03 ± 0.06	28.14 ± 0.55	−0.10 ± 0.18	28.27 ± 0.55	0.06 ± 0.05	.88	.42	.49	.21
Adjusted	28.26 ± 0.58	0.02 ± 0.06	28.09 ± 0.59	−0.10 ± 0.20	28.22 ± 0.58	0.03 ± 0.05	.69	.39	.57	.32
Visceral fat (%)										
Crude	9.52 ± 0.45	−0.12 ± 0.18	9.51 ± 0.46	0.06 ± 0.07	9.45 ± 0.44	0.01 ± 0.06	.94	.36	.78	.65
Adjusted	9.39 ± 0.47	−0.13 ± 0.19	9.37 ± 0.48	0.07 ± 0.07	9.29 ± 0.46	−0.03 ± 0.06	.67	.37	.60	.70
Body fat (%)										
Crude	34.26 ± 1.34	0.15 ± 0.14	34.24 ± 1.36	0.19 ± 0.16	34.21 ± 1.34	0.32 ± 0.12	.004	.57	.66	.72
Adjusted	34.21 ± 1.39	0.13 ± 0.15	34.23 ± 1.42	0.25 ± 0.16	34.20 ± 1.39	0.31 ± 0.13	.004	.63	.68	.72
Muscle mass (%)[h]										
Crude	29.12 ± 1.25	−0.62 ± 0.30	28.17 ± 1.31	−0.66 ± 0.31	28.89 ± 1.17	−0.96 ± 0.27	<.001	.51	.62	.09
Adjusted	29 ± 0.46	−0.59 ± 0.30	28.67 ± 0.49	−0.62 ± 0.33	28.58 ± 0.43	−1.01 ± 0.28	<.001	.47	.60	.08
WC (cm)										
Crude	96.80 ± 1.21	−0.86 ± 0.26	97.03 ± 1.29	−0.65 ± 0.24	96.92 ± 1.20	−0.49 ± 0.27	<.001	.82	.64	.81
Adjusted	96.60 ± 1.28	−0.93 ± 0.23	96.89 ± 1.37	−0.67 ± 0.25	96.86 ± 1.27	−0.61 ± 0.27	<.001	.78	.52	.82
HC (cm)[h]										
Crude	106.87 ± 1.89	−0.19 ± 0.30	105.26 ± 1.98	−0.45 ± 0.32	104.84 ± 1.78	−0.50 ± 0.28	.03	.63	.75	.40
Adjusted	105.39 ± 0.82	−0.32 ± 0.32	105.33 ± 0.88	−0.43 ± 0.35	106.35 ± 0.76	−0.44 ± 0.30	.03	.57	.80	.50
WHR										
Crude	0.92 ± 0.008	−0.004 ± 0.003	0.92 ± 0.008	−0.004 ± 0.002	0.92 ± 0.008	0.000 ± 0.002	.04	.92	.40	.69
Adjusted	0.92 ± 0.008	−0.005 ± 0.002	0.92 ± 0.008	−0.004 ± 0.002	0.92 ± 0.008	−0.001 ± 0.002	.01	.89	.30	.61
ICO										
Crude	0.59 ± 0.009	−0.005 ± 0.002	0.59 ± 0.009	−0.004 ± 0.002	0.59 ± 0.009	−0.003 ± 0.002	<.001	.82	.63	.79
Adjusted	0.59 ± 0.01	−0.007 ± 0.002	0.59 ± 0.01	−0.005 ± 0.002	0.59 ± 0.01	−0.004 ± 0.002	<.001	.77	.53	.82
BAI[h]										
Crude	33.01 ± 1.47	−0.11 ± 0.14	33.31 ± 1.54	−0.22 ± 0.15	32.71 ± 1.39	−0.23 ± 0.13	.02	.89	.80	.92
Adjusted	32.04 ± 0.57	−0.16 ± 0.15	33.06 ± 0.62	−0.21 ± 0.16	33.77 ± 0.54	−0.21 ± 0.14	.02	.90	.84	.95

[a]BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist to hip ratio; BAI: body adiposity index; ICO: index of central obesity.
[b]p Values for time effect using linear mixed effects model.
[c]p Values for treatment effect using linear mixed effects model.
[d]p Values for treatment × time interaction using linear mixed effects model.
[e]p Values for treatment × gender interaction using linear mixed effects model.
[f]Values are reported as mean ± standard error (SE).
[g]Adjusted for age, BMI, the calculated intervention oils consumed per subject, physical activity level and the energy intake in each intervention period.
[h]The values are reported for the first phase because carry over effect was seen; SO ($n=23$), SCO ($n=22$) and CO ($n=26$).

Table 3. After and change values for body weight and composition measurements based on the intervention periods in female participants[a].

	Sesame oil ($n = 40$)		Sesame-canola oil ($n = 41$)		Canola oil ($n = 38$)				
	After	Change	After	Change	After	Change	p^b	p^c	p^d
Body weight (kg)									
Crude	72.97 ± 1.50[e]	−0.008 ± 0.24	72.18 ± 1.61	−0.77 ± 0.80	72.74 ± 1.48	0.14 ± 0.19	.40	.15	.41
Adjusted[f]	73.19 ± 1.58	−0.03 ± 0.24	72.42 ± 1.71	−0.70 ± 0.86	72.97 ± 1.56	0.08 ± 0.19	.38	.17	.46
BMI (kg/m^2)									
Crude	29.31 ± 0.75	0.002 ± 0.09	28.99 ± 0.77	−0.31 ± 0.33	29.22 ± 0.76	0.06 ± 0.07	.40	.14	.41
Adjusted	29.31 ± 0.80	−0.009 ± 0.09	29 ± 0.82	−0.28 ± 0.35	29.24 ± 0.80	0.04 ± 0.07	.38	.18	.46
Visceral fat (%)									
Crude	8.14 ± 0.34	−0.23 ± 0.29	8.15 ± 0.34	−0.02 ± 0.07	8.08 ± 0.33	0.03 ± 0.06	.52	.08	.52
Adjusted	8.10 ± 0.36	−0.22 ± 0.30	8.10 ± 0.36	0.01 ± 0.07	8.01 ± 0.35	0.002 ± 0.06	.49	.11	.68
Body fat (%)									
Crude	42.31 ± 0.88	0.34 ± 0.17	42.36 ± 0.90	0.14 ± 0.18	42.27 ± 0.88	0.30 ± 0.13	.01	.39	.73
Adjusted	42.18 ± 0.93	0.29 ± 0.17	42.30 ± 0.95	0.24 ± 0.18	42.16 ± 0.93	0.28 ± 0.14	.01	.41	.87
Muscle mass (%)[g]									
Crude	24.33 ± 0.57	−0.97 ± 0.49	24.75 ± 0.55	−0.56 ± 0.48	23.58 ± 0.51	−1.07 ± 0.44	.002	.54	.66
Adjusted	24.59 ± 0.50	−1.24 ± 0.50	25.10 ± 0.49	−0.15 ± 0.48	23.21 ± 0.42[b]	−1.22 ± 0.42	.004	.45	.76
WC (cm)									
Crude	96.10 ± 1.67	−1.24 ± 0.30	96.54 ± 1.81	−0.78 ± 0.33	96.04 ± 1.66	−0.70 ± 0.42	<.001	.83	.77
Adjusted	96.14 ± 1.78	−1.11 ± 0.28	96.48 ± 1.93	−0.70 ± 0.34	96.11 ± 1.76	−0.80 ± 0.41	<.001	.74	.85
HC (cm)[g]									
Crude	109.91 ± 2.59	−0.54 ± 0.45	106.46 ± 2.49	−0.53 ± 0.44	109.23 ± 2.32	−0.46 ± 0.41	.04	.56	.99
Adjusted	108.02 ± 1.11	−0.83 ± 0.52	107.67 ± 1.08	−0.28 ± 0.50	110.07 ± 0.93	−0.56 ± 0.43	.04	.64	.96
WHR									
Crude	0.89 ± 0.008	−0.008 ± 0.003	0.89 ± 0.009	−0.003 ± 0.004	0.89 ± 0.009	−0.002 ± 0.003	.008	.62	.61
Adjusted	0.89 ± 0.00	−0.007 ± 0.002	0.89 ± 0.01	−0.003 ± 0.004	0.89 ± 0.00	−0.003 ± 0.003	.01	.64	.70
ICO									
Crude	0.60 ± 0.01	−0.01 ± 0.003	0.61 ± 0.01	−0.008 ± 0.003	0.60 ± 0.01	−0.008 ± 0.003	<.001	.81	.78
Adjusted	0.60 ± 0.01	−0.01 ± 0.003	0.61 ± 0.01	−0.009 ± 0.003	0.60 ± 0.01	−0.010 ± 0.003	<.001	.73	.87
BAI[g]									
Crude	37.48 ± 1.97	−0.26 ± 0.22	36.54 ± 1.89	−0.27 ± 0.21	36.56 ± 1.76	−0.22 ± 0.20	.05	.91	.98
Adjusted	35.41 ± 0.80	−0.40 ± 0.25	37.30 ± 0.78	−0.15 ± 0.25	37.45 ± 0.67	−0.26 ± 0.21	.04	.94	.94

[a]BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist to hip ratio; BAI: body adiposity index; ICO: index of central obesity.
[b]p Values for time effect using linear mixed effects model.
[c]p Values for treatment effect using linear mixed effects model.
[d]p Values for treatment × time interaction using linear mixed effects model.
[e]Values are reported as mean ± standard error (SE).
[f]Adjusted for age, BMI, the calculated intervention oils consumed per subject, physical activity level and the energy intake in each intervention period.
[g]The first phase values are reported because carry over effect was seen for these variables; SO ($n = 12$), SCO ($n = 13$) and CO ($n = 15$).

healthy diet (Namiki 2007; Lin et al. 2013). To the best of our knowledge, the current study is the first one comparing the effects of SO and CO on anthropometric parameters. Our findings demonstrated that in all treatment periods, a significant decrease was shown in muscle mass, WC, HC, WHO, ICO and BAI. In contrast, body fat was increased in all intervention periods in the total population. The same findings were found in females. A significant decrease was only indicated in muscle mass, WC and ICO in males.

The intervention oils had no significant effect on body weight; however, we observed a decreasing effect on central obesity indices (WC, HC and ICO) in the study period. Therefore, the results might strengthen the hypothesis that SO, CO and SCO might affect body fat distribution. In support of our results, Paniagua et al. (2007) have indicated that macronutrient composition of diets might influence the distribution of body fat without affecting body weight. They reported that MUFA-rich diets in comparison with a low-fat carbohydrate-rich diet can decrease abdominal-fat to leg-fat ratio due to increasing fat oxidation rate. In addition, they asserted that macronutrient composition of isocaloric diets during the short run intervention did not affect body weight. In a randomised crossover trial conducted by Liu et al. (2016), it is reported that high MUFA diets (canola-oleic oil and CO diets) had reducing effect on android fat mass (about 3%), as an ICO. They reported no changes in the gynoid fat mass, indicating that the adipose tissue did not redistribute to the lower part of the body and MUFA-rich diets exclusively affected the central obesity. Moreover, some evidence indicated that a diet rich in MUFAs lead to less fat deposition when compared to high SFA diet (Piers et al. 2002). It is also reported that the amount of n-3 fatty acids and MUFAs in adipose tissue are inversely correlated with central obesity (Garaulet et al. 2001). In contrast, in a well-designed study conducting by Shai et al. (2008) which assessed three types of diet including low-fat, restricted-calorie diet; Mediterranean, restricted-calorie

Table 4. After and change values for body weight and composition measurements based on the intervention periods in male participants[a].

	Sesame oil ($n=30$)		Sesame-canola oil ($n=32$)		Canola oil ($n=31$)				
	After	Change	After	Change	After	Change	p^b	p^c	p^d
Body weight (kg)									
Crude	78.77 ± 2.56[e]	0.26 ± 0.24	78.78 ± 2.62	0.44 ± 0.24	78.79 ± 2.60	0.32 ± 0.22	.04	.91	.79
Adjusted[f]	78.48 ± 2.79	0.23 ± 0.27	78.48 ± 2.86	0.34 ± 0.25	78.51 ± 2.83	0.20 ± 0.24	.13	.90	.71
BMI (kg/m^2)									
Crude	27.10 ± 0.81	0.08 ± 0.08	27.09 ± 0.82	0.14 ± 0.08	27.10 ± 0.82	0.11 ± 0.08	.053	.96	.81
Adjusted	26.97 ± 0.89	0.07 ± 0.09	26.96 ± 0.90	0.11 ± 0.08	26.97 ± 0.90	0.07 ± 0.08	.15	.95	.73
Visceral fat (%)									
Crude	11.39 ± 0.86	0.05 ± 0.16	11.35 ± 0.89	0.22 ± 0.14	11.32 ± 0.84	0.02 ± 0.10	.41	.85	.57
Adjusted	11.26 ± 0.94	0.03 ± 0.18	11.23 ± 0.97	0.20 ± 0.15	11.16 ± 0.92	−0.04 ± 0.10	.61	.97	.35
Body fat (%)									
Crude	23.98 ± 1.23	−0.10 ± 0.25	23.80 ± 1.32	0.25 ± 0.29	23.88 ± 1.22	0.43 ± 0.20	.15	.77	.72
Adjusted	23.97 ± 1.34	−0.09 ± 0.27	23.84 ± 1.45	0.28 ± 0.31	23.98 ± 1.34	0.51 ± 0.22	.11	.78	.67
Muscle mass (%)[g]									
Crude	34.35 ± 1	−0.20 ± 0.23	33.73 ± 1.17	−0.83 ± 0.28	36.12 ± 1	−0.82 ± 0.22	<.001	.24	.16
Adjusted	34.70 ± 0.59	−0.10 ± 0.25	34.26 ± 0.74	−0.93 ± 0.36	35.58 ± 0.61	−0.85 ± 0.25	.001	.24	.20
WC (cm)									
Crude	98.03 ± 1.85	−0.25 ± 0.44	97.74 ± 1.97	−0.58 ± 0.36	98.23 ± 1.76	−0.19 ± 0.33	.06	.75	.64
Adjusted	97.78 ± 2.02	−0.61 ± 0.41	97.67 ± 2.15	−0.78 ± 0.38	98.21 ± 1.94	−0.26 ± 0.36	.004	.82	.54
HC (cm)[g]									
Crude	103.54 ± 2.30	0.18 ± 0.39	103.31 ± 2.70	−0.31 ± 0.46	98.86 ± 2.30	−0.54 ± 0.39	.37	.38	.46
Adjusted	101.48 ± 1.23	−0.13 ± 0.37	102.85 ± 1.55	−0.20 ± 0.46	101.12 ± 1.30	−0.25 ± 0.38	.39	.40	.49
WHR									
Crude	0.97 ± 0.01	0.003 ± 0.004	0.96 ± 0.01	−0.005 ± 0.003	0.97 ± 0.009	0.002 ± 0.004	.95	.74	.26
Adjusted	0.97 ± 0.01	−0.001 ± 0.004	0.96 ± 0.01	−0.006 ± 0.004	0.97 ± 0.01	0.002 ± 0.004	.43	.52	.30
ICO									
Crude	0.57 ± 0.01	−0.003 ± 0.002	0.57 ± 0.01	−0.003 ± 0.002	0.57 ± 0.01	0 ± 0.002	.06	.75	.61
Adjusted	0.57 ± 0.01	−0.005 ± 0.002	0.57 ± 0.01	−0.003 ± 0.002	0.57 ± 0.01	−0.002 ± 0.002	.004	.81	.52
BAI[g]									
Crude	28.13 ± 0.92	0.06 ± 0.17	28.05 ± 1.08	−0.13 ± 0.20	27.45 ± 0.92	−0.25 ± 0.17	.31	.90	.46
Adjusted	27.40 ± 0.45	−0.08 ± 0.16	27.74 ± 0.57	−0.08 ± 0.20	28.30 ± 0.48	−0.12 ± 0.17	.35	.89	.53

[a]BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist to hip ratio; BAI: body adiposity index; ICO: index of central obesity.
[b]p Values for time effect using linear mixed effects model.
[c]p Values for treatment effect using linear mixed effects model.
[d]p Values for treatment × time interaction using linear mixed effects model.
[e]Values are reported as mean ± standard error (SE).
[f]Adjusted for age, BMI, the calculated intervention oils consumed per subject, physical activity level and the energy intake in each intervention period.
[g]The first phase values are reported because carry over effect was seen for these variables; SO ($n=11$), SCO ($n=9$) and CO ($n=11$).

diet; or low-carbohydrate, non-restricted-calorie diet on weight loss, it is reported that weight reduction was greater in low-carbohydrate diet and Mediterranean diets which were high in MUFAs. In addition, in a recent meta-analysis conducting by Raeisi-Dehkordi et al. (2019) on the effect of CO on body weight and composition, it was reported that the consumption of CO may lead to a modest decrease in body weight, whereas it did not affect other anthropometric markers. Increasing oxidation rate and energy expenditure as a result of high-MUFAs diets can be noted as possible mechanisms for reducing central adiposity indices. Increasing fatty acid oxidative capacity may be due to the activation of peroxisome proliferator-activated receptor δ (PPAR-δ) as a result of MUFA consumption (Ravnskjaer et al. 2010; Bojic and Huff 2013). In addition, oleoylethanolamide, as a derivative of oleic acid, can be effective in activation of PPAR-α and result in lipolysis (Fu et al. 2003). Therefore, body composition change is expected after high-MUFA diets. To vindicate our results which treatment oils had no reducing effects on body fat percent, it has been shown that providing more than 50% of total energy from fat may be effective in metabolic response to dietary fat intake (Flint et al. 2003; Jones et al. 2008; Casas-Agustench et al. 2009), while in this study, treatment oils were replaced with ordinary consumed oils comprising 30–32% of total energy intake.

Sankar et al. (2006a) showed that substitution of SO for 45 days in patients with hypertension has beneficial effects on body weight and BMI, whereas after withdrawal of SO consumption these anthropometric markers were increased again which is in contrary with our findings. It should be noted that the mentioned study was a one arm before-after study and the participants were not blind to the intervention oils. Therefore, the results of the study might not be reliable. In a meta-analysis assessing the effects of sesame seed and its products on body weight and composition, it was shown that sesame consumption had reducing effect on the body fat percent and BAI, while SO decreased body weight and BMI without affecting

other anthropometric measurements (Raeisi-Dehkordi et al. 2018). As it was mentioned in both meta-analyses (Raeisi-Dehkordi et al. 2018, 2019), a limited number of studies have strictly investigated the effect of SO and CO on body weight and composition. Moreover, most of the eligible studies in both meta-analyses were conducted in individuals with chronic conditions; however, our study investigated the intervention oils on adults. Furthermore, the included studies used specific amounts of dietary oils for intervention, whereas in the current study the substitution of regularly consumed oils with sesame, canola and SCO were investigated on individuals without chronic conditions.

Due to the cross-over design of the present study, each subject acted as his/her own control, and this minimised the impact of between person variations on the results. Furthermore, replacing ordinary edible oils with treatment oils makes the current results closer to the real life. There are some limitations that should be considered while interpreting our results. As edible oils usually used by study participants in their home were replaced by the intervention oils, the research team was not able to determine the exact amount of consumed treatment oils in participants; however, it is worth noting that we tried to calculate the oils consumed per day by weighing the provided and returned oil and using the weighted dietary food records. Our results indicated that the intervention oils reduced muscle mass. Since this study was the first clinical trial which replaced commonly consumed oils with the intervention oils, there is not any justification for the observed results. Furthermore, to the best our knowledge, the majority of dietary oil intervention studies did not present data for the effect of dietary oils on muscle mass. The present study used a bioimpedance analyser to assess visceral fat, total body fat and muscle mass which is a more frequent although less accurate tool to assess body composition assessment compared to more valid methods like whole body potassium counting and dual-energy X-ray absorptiometry (DXA) that are suggested to be used in clinical research (Branski et al. 2010). It should also be noted that the BIA allows the estimation of the body compartments through equations. The BIA is therefore not a direct method of body composition assessment and the accuracy of the compartment's estimation depends largely on the choice of appropriate predictive equations. Therefore, the presented results on body composition measurements in the current study should be interpreted by caution. As the present study aimed to evaluate the effect of dietary oils on abdominal/visceral fat, the results on WC might be more reliable. In this context, further well-designed dietary oil substitution studies are needed to elucidate the effect of intervention oils on this parameter.

In conclusion, the present investigation provides evidence that the three treatment oils including SO, CO and SCO may be effective in improvement of central obesity, while no significant effect on body weight, BMI and visceral fat was observed. In addition, all intervention periods showed a significant reducing effect on HC, WHR and BAI. Therefore, the intervention oils might affect body fat distribution rather than affecting body weight. We found that the intervention oils might have decreasing effects on muscle mass. Nevertheless, the present clinical trial revealed that CO, SO and SCO might not differently affect body fat and composition. Further well-designed studies should be conducted to confirm these results.

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Author Contributions

ASA contributed to study concept and supervision. The study protocol was designed by ASA and MA. Recruitment of the study participants were carried out by MA and MR. FM and MA had role in data collecting. HR and AZ had responsibility for laboratory analyses. The data entry was carried out by MA, HR, FM and AZ. ASA and HF provided counseling for statistical analysis. ASA and MH played a role in counseling throughout the study. ASA and FM wrote the first draft of the manuscript. All authors read and approved the final version of manuscript.

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