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Review

Can avocado intake improve weight loss in adults with excess weight? A systematic review and meta-analysis of randomized controlled trials

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ABSTRACT

The effect of avocado (*Persea Americana*) on weight loss in people with excess body weight remains unclear. Therefore, we aimed to test our hypothesis that the intake of avocado pulp may be a good strategy for improving anthropometric parameters and, consequently, metabolic health. For this systematic review and meta-analysis, we searched MEDLINE/PubMed, EMBASE, and the Cochrane Central Register of Controlled Trials (CENTRAL) for studies published between database inception and July 2021. Randomized clinical trials (RCTs) assessing avocado intake on anthropometric parameters (primary outcome) and metabolic parameters (secondary outcomes) were included. Evidence from RCTs were synthesized as differences between standardized mean differences (SMDs) for change in body weight and body composition, comparing the experimental avocado group with control via random-effects meta-analyses. The risk of bias followed the Joanna Briggs Institute Reviewer's Manual. From 781 records identified, 8 studies with 657 individuals were included. No significant changes in body weight, body mass index, percent of body fat, or visceral adipose tissue in response to intervention was seen in the avocado group compared with the control group. Also, the pooled results showed no reduction in body weight and composition (SMD = 0.09; 95% confidence interval, 0.06-0.25; P= .25; I^2 = 0%) of avocado in comparison to control. Secondary outcomes showed some potential benefits in metabolic parameters, mainly related to lipid profile. Regardless, consumption of avocado did not promote weight gain, and further studies are needed to elucidate this effect. The PROSPERO register number of this study is CRD42021266488.

Abbreviations: Apo, apolipoprotein; BMI, body mass index; CI, confidence interval; CRP, C-reactive protein; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, homeostasis model assessment for insulin resistance; IL, interleukin; JBI, Joanna Briggs Institute; LDL-C, low-density lipoprotein; MUFA, monounsaturated fatty acid; NCD, noncommunicable disease; oxLDL, oxidized LDL; PUFA, polyunsaturated fatty acid; RCT, randomized clinical trial; SFA, saturated fatty acid; SMD, standardized mean difference; TC, total cholesterol; TG, triglyceride; VAT, visceral adipose tissue; VLDL-C, very low-density lipoprotein; VS ratio, visceral to subcutaneous abdominal adipose ratio.

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1. Introduction

Overweight and obesity are defined as abnormal or exaggerated fat accumulation that can harm health [1]. The issue has reached epidemic proportions worldwide, with severe consequences for modern society [1]. The prevalence of obesity has risen rapidly in many countries, showing an increasing rate of 3 times more from 1975 to 2016 [1]. Notably, if this trend continues, by 2025, the prevalence of this global disease will be 18% in men and will exceed 21% in women, imposing a challenge to health systems [2]. Moreover, obesity has high morbidity and mortality involved in the etiology of chronic noncommunicable diseases (NCDs) such as type 2 diabetes, cardiovascular diseases, and several cancer types. NCDs are responsible for 71% of deaths worldwide [3] and a loss to the global economy will reach US$47 trillion in 2030 [4].

Although obesity has a complex and multifactorial etiology, it is preventable [5]. Globalization has resulted in sociocultural modifications that influenced diet and lifestyle, including higher consumption of energy-dense foods such as ultra-processed and fast foods and a sedentary lifestyle with a subsequent reduction in energy expenditure [6]. These changes promoted a substantial increase in obesity and NCDs [7].

Therefore, there is a growing need for prevention strategies and control of excess weight and its comorbidities. Weight loss has been considered an optimal approach to obesity treatment. A modest decrease of 5% to 10% of body weight was associated with significant metabolic parameters improvement [8]. To promote weight loss, it is essential to establish energetic homeostasis by reducing caloric consumption and/or increasing energy expenditure [9]. It has been demonstrated that low-calorie diet interventions help reduce short- and long-term weight in individuals with overweight or obesity [10]. The role of diet composition is also relevant. It has been investigated extensively [11], with evidence that the quantity and quality of macronutrients also contribute to weight loss through the regulation of satiety [11, 12].

Furthermore, several foods rich in bioactive compounds have been essential allies in treating obesity [13,14]. Among them is the Hass avocado fruit (*Persea Americana*), which has a unique nutrient profile. Its low-medium energy density stands out, approximately 72% of its weight is water, it is low in sugar (0.2 g of sugar/half of the fruit) [15], and it presents high palatability and sensory quality [16]. On average, 1 Hass avocado provides ~250 kcal, 21 g fat (76% energy), 11.8 g carbohydrate (19% energy), 2.7 g protein (4% energy), and soluble and insoluble dietary fibers (~9.2 g of total fiber) [15]. Consequently, avocado consumption has been reported to improve cardiometabolic parameters in hyperlipidemia, inflammation, blood pressure, blood glucose, insulin concentrations, and metabolic syndrome [17,18]. Additionally, habitual avocado intake is associated with a lower prevalence of excess weight and attenuates adult weight gain in normal-weight individuals over time [19].

Many studies examined the relationship between avocado intake and its effect on plasma lipoproteins and cardiovascular disease [18,20]. Nevertheless, no systematic review is dedicated to ascertaining the impact of avocado consumption on weight loss and body composition changes. Moreover, the findings seem to be mixed in the few human intervention studies that have been conducted on this topic [21]. In this manner, we hypothesized that the intake of avocado pulp might be an excellent strategy to improve anthropometric parameters and consequently metabolic health. Therefore, this systematic review and meta-analysis aimed to assess whether avocado intake can stimulate weight loss and improve body composition and metabolic parameters among adults with excess weight.

Table 1 – Criteria for inclusion of studies

Parameter	Inclusion criteria
Population	Individuals ≥18 years old with BMI ≥25 kg/m²
Intervention	Avocado intake
Comparison	No avocado intake
Outcomes	Changes in anthropometric and metabolic parameters
Study design	Randomized clinical trials

BMI, body mass index.

2. Methods

2.1. Protocol and registration

The present systematic review was redacted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses [22]; its checklist is provided in Supplementary Table S1. It was registered on PROSPERO (International Prospective Register of Ongoing Systematic Reviews, CRD42021266488).

2.2. Search strategy

To identify the eligible studies, we used the anagram PICOS (population, intervention, comparison, outcomes, and study design) in which the central question was: "Can avocado intake improve anthropometric and/or metabolic parameters in adults with excess weight?" Table 1 lists the PICOS criteria adopted in this review.

The search used MEDLINE/PubMed, EMBASE, and Cochrane Central Register of Controlled Trials (CENTRAL) databases for eligible articles by 2 authors (A.R.C. and G.M.F.) in parallel and independently, in July 2021, without language and date restrictions of publication. The descriptors used were following the Medical Subject Headings or the Emtree terms in English. We used the Boolean operators OR and AND at the time of searches to associate the terms. Validated filters for identifying randomized clinical trials (RCTs) were used in 2 databases (MEDLINE/Pubmed and EMBASE) [23,24]. The detailed search strategy for each database is described in Table 2. Two reviewers (A.R.C. and G.M.F.) manually searched the reference lists of studies selected in the previous step independently to find additional relevant articles.

2.3. Eligibility criteria

To include the studies, the following criteria were as follows: (1) original RCTs; (2) individuals with ≥18 years and body

Table 2 – Full search strategy in PubMed, EMBASE, and CENTRAL including search terms and filters

Database	Search criteria
PubMed	("persea"[MeSH Terms] OR "persea"[All Fields] OR "perseas"[All Fields] OR "perseae"[All Fields] OR "persea"[MeSH Terms] OR ("persea"[MeSH Terms] OR "persea"[All Fields] OR "avocado"[All Fields] OR "avocados"[All Fields]) OR ("persea"[MeSH Terms] OR "persea"[All Fields] OR "perseas"[All Fields] OR "perseae"[All Fields]) OR ("persea"[MeSH Terms] OR "persea"[All Fields] OR ("persea"[All Fields] AND "americana"[All Fields]) OR "persea americana"[All Fields]) OR ("persea"[MeSH Terms] OR "persea"[All Fields] OR ("persea"[All Fields] AND "americanas"[All Fields])) OR ("persea"[MeSH Terms] OR "persea"[All Fields] OR "avocado"[All Fields] OR "avocados"[All Fields]) OR ("persea"[MeSH Terms] OR "persea"[All Fields] OR ("americana"[All Fields] AND "persea"[All Fields]))) AND (("randomized controlled trial"[Publication Type] OR "controlled clinical trial"[Publication Type] OR "randomized"[Title/Abstract] OR "placebo"[Title/Abstract] OR "drug therapy"[MeSH Subheading] OR "randomly"[Title/Abstract] OR "trial"[Title/Abstract] OR "groups"[Title/Abstract]) NOT ("animals"[MeSH Terms] NOT "humans"[MeSH Terms]))
EMBASE	('avocado'/exp OR 'persea americana' OR 'avocado' OR 'persea'/exp OR 'persea') AND (random*:ab,ti OR ((clinical NEXT/1 trial*):de,ab,ti) OR 'health care quality'/exp)
CENTRAL	(Persea OR Perseas OR Avocado OR Avocados OR Persea americana OR Persea americanas OR Americana, Persea) in All Text (Word variations have been searched)

MESH, medical subject heading.

mass index (BMI) ≥25 kg/m² with or without cardiometabolic diseases; and (3) avocado intake (pulp). The primary outcome of interest was changes in the anthropometric parameters. Modifications in metabolic parameters were considered as secondary outcomes. The noninclusion criteria were as follows: (1) publications that did not report original data, such as letters, comments, or reviews; (2) publications with a design that are not RCTs, such as nonrandomized trials, case control, cohort, and cross-sectional; (3) studies that used parts of avocado other than pulp, such as oil, leaves, peel, and seed; (4) investigation of outcome other than the changes in health parameters mentioned previously; and (5) interventions with physical activity associated with avocado intake.

2.4. *Study selection and data collection process*

The relevant studies were identified by screening the titles, abstracts, and full texts. Each database's search results were imported into the Rayyan QCRY Software [25] to exclude duplicates. In the same software, 2 researchers (A.R.C. and G.M.F.) carried out the study selection process, in a double-blind manner, independently and in parallel. In case of disagreement during the title and abstract evaluation process, we kept the article in the next step. We used institutional access to obtain complete manuscripts. After full reading, the authors resolved disagreements by consensus. The level of agreement between these reviewers was assessed using Kappa (Kappa = 0.936).

The following data were extracted from each study: authors and year of publication, study design, characteristics of participants, avocado type and amount, characteristics of intervention and duration, and main results. This information was summarized in a standard data extraction template using Microsoft Excel (2020). Data were expressed in the form of tables and figures. The first reviewer (A.R.C.) extracted data using a standardized form containing the variables of interest (Table 3), these were then verified by the second reviewer independently (GMF), and the discrepancies were solved by consensus. The process design and the workflow are in Fig. 1.

2.5. *Risk-of-bias assessment*

All 8 articles selected for inclusion in the systematic review were subjected to rigorous evaluation by 2 independent reviewers (A.R.C. and G.M.F.); disagreements were solved by an independent assessment of a third author (J.B.). The risk of bias followed the Joanna Briggs Institute (JBI) Reviewer's Manual [26] through Critical Analysis Tools, developed by the JBI and approved by the JBI Scientific Committee after an extensive peer review. The JBI Manual claims that the authors should state a priori the criteria used to determine the score to appoint each study's level of bias [27]. Considering that, the reviewers selected through the percentage of affirmative responses ("yes"): low ≥ 70%, moderate between 50% to 69%, and high risk of bias < 50% (Supplementary Table S2).

2.6. *Statistical analysis*

We conducted meta-analyses on primary outcomes that encompass changes in body weight and composition (i.e., body weight, BMI, % fat mass, and visceral adipose tissue [VAT]). All outcomes were continuous measures, and we used standardized mean differences (SMDs) to express the selected effect size. When median, standard errors, or ranges were provided, we calculated mean and standard deviations with standard formulae. Also, when necessary, we imputed changes from baseline results when information of variables before and after the intervention was provided. The random-effects model was used considering the heterogeneity of interventions. Heterogeneity (low: <50%; moderate to high: 50%-75%; high: >75%) was assessed by the application of I^2 statistics. Results were considered significant for a $P < .05$ for all analyses. Sensitivity analysis was performed to quantify the effect on results by deleting 1 study at a time from the meta-analysis. Review Manager (RevMan), version 5.4, from the Cochrane Collaboration (2020), was used for data synthesis. Primary outcomes were assessed in only 1 study, and secondary outcomes were not included in the meta-analysis and were qualitatively described.

Table 3 – Characteristics of articles included in systematic review and meta-analysis

Reference	Study design	Charact eristics of participants	Avocado type	Avocado amount	Intervention groups	Intervention duration	Primary outcomes[a]	Secondary outcomes[a]
Pieterse et al. [28]	Randomized, controlled, parallel study	n = 55 Sex = not specified Mean age = 40.8 ± 8.94 y	Not stated	200 g/d	Hypocaloric diet (calorie deficit NA) + Avocado (n= 28) Hypocaloric diet (calories deficit NA) without avocado (control) (n = 27)	6 wk	↔ Bodyweight, BMI, % total body fat	↔ Myristic, oleic, α-linolenic, palmitic, stearic, linoleic, TC, LDL, TG, HDL, plasma fibrinogen, arterial compliance, SBP, DBP
Wang et al. [b] [34]	Randomized, crossover, controlled feeding trial	n = 45 Sex = not specified Mean age = 45 ± 13.3 y	Hass avocado	~136 g	Lower-fat diet without avocado (LF, 24% fat) (n = 43) Moderate-fat diet without avocado (MF, 34% fat) (n=42) Avocado (AV, 34% fat) (n=43)	21 wk	Not evaluated	↓ TC, non-HDL, LDL (AV vs. LF and MF), ILD, VLDL, HDL, TG, ApoB, ApoB:ApoA1 (AV and MF vs. LF), TC:HDL, LDL:HDL, TG:HDL (AV vs. MF vs. LF) ↑ LP(a) (AV vs. LF) ↔ ApoA1, glucose, insulin, hsCRP, HOMA, SBP, DBP
Henning et al. [29]	Prospective, randomized, parallel, 2-arm, open-label intervention study	n = 51 Sex = 20 F, 31 M Mean age AV group = 42.5 ± 12.7 Mean age CTRL group= 36.4±10.8	Hass avocado	One avocado daily (136g)	Hypocaloric diet (500 calories deficit) + avocado (n = 24) Hypocaloric diet (500 calorie deficit) without avocado (control) (n = 27)	12 weeks	↔ Bodyweight, BMI, % total body fat, VAT	↓ HGF and α-linolenic acid ↑ Glucose ↔ Satiety score, insulin, TC, HDL, LDL, TG, NGF, IL-6, IL1-β, CRP, leptin, MCP1, TNF-α, adiponectin, resistin, PAI, myristic, palmitic, stearic, oleic, linoleic, arachidonic, eicosapentaenoic, docosapentaenoic, and docosahexaenoic acid
Edwards et al. [30]	Randomized controlled trial	n = 84 Sex = 53 F, 31 M Mean age avocado group = 34.6 ± 5.7 Mean age control group= 34.0±6.2	Hass avocado	F: 140 g M: 175 g	Avocado (n = 47) Control (n = 37)	12 wk	↔ BMI and % total body fat	Not evaluated

(*continued on next page*)

Table 3 (*continued*)

Reference	Study design	Charact eristics of participants	Avocado type	Avocado amount	Intervention groups	Intervention duration	Primary outcomes[a]	Secondary outcomes[a]
Hannon et al. [33]	Randomized controlled trial	n = 115 Sex = 73 F, 42 M Mean age = 35.7 ± 0.6 y	Hass avocado	F: 140 g M: 175 g	Avocado (n = 61) Control (n = 54)	12 wk	Not evaluated	↔ TC, HDL, TG, intake of kilocalories, total fat, or carbohydrates as a percentage of total energy, meal consumption adherence
Wang et al. [b] [35]	Randomized, crossover, controlled feeding trial	n = 45 Sex = not specified Mean age = 45 ± 13.3 y	Hass avocado	~136 g	Lower fat diet without avocado (LF, 24% fat) (n = 43) Moderate-fat diet without avocado (MF, 34% fat) (n = 42) Avocado (AV, 34% fat) (n=43)	21 wk	Not evaluated	↑ Lutein (AV vs. LF and MF), α-carotene (MF vs. LF) ↓ oxLDL (AV vs. LF and MF), CETP activity (AV vs. MF) ↔ δ-tocopherol, γ-tocopherol, α-tocopherol, β-carotene, F2-isoprostane, retinol, PLTP, LCAT, VCAM1, ICAM1, MCP1, and IL1-β
Thompson et al. [31]	Investigator-blinded, parallel-arm, randomized controlled trial	n = 157 Sex = 100 F, 57 M Mean age = 35 ± 0.5 y	Hass avocado	F: 140 g M: 175 g	Avocado (n = 79) Control (n = 78)	12 wk	↔ Bodyweight (n = 109)[c]	↑ MUFA, total dietary fiber, insoluble dietary fiber, soluble dietary fiber, and pectin (n = 106)[c] ↔ Total energy, total fat, saturated fat, PUFA, total carbohydrates, and total protein
Khan et al. [32]	Randomized controlled trial	n = 105 Sex = 64 F, 41 M Mean age = 34.5 ± 5.9 y	Hass avocado	F: 140 g M: 175 g	Avocado (n = 52) Control (n = 53)	12 wk	↑ SAAT ↓ VS ratio, Δ VAT, Δ SAAT, and Δ VS Ratio in females ↔ VAT	↔ HOMA-IR, Matsuda index, and insulinogenic index

ApoA1, apolipoprotein A1; ApoB, apolipoprotein B; BMI, body mass index; CETP, cholesterol ester transfer protein; CRP, C-reactive protein; DBP, diastolic blood pressure; HDL, high-density lipoprotein; HGF, hepatic growth factor; hs-CRP, high-sensitivity C-reactive protein; ICAM1, intercellular adhesion molecule 1; IDL, intermediate-density lipoprotein; IL, interleukin; LCAT, lecithin/cholesterol acyltransferase; LDL, low-density lipoprotein; LP(a), lipoprotein a; MCP-1, monocyte chemoattractant protein-1; MUFA, monounsaturated fatty acid; NA, not available; NGF, nerve growth factor; oxLDL, oxidized low-density lipoprotein; PAI, plasminogen activator inhibitor-1; PLTP, phospholipid transfer protein; PUFA, polyunsaturated fatty acid; SAAT, subcutaneous abdominal adipose tissue; SBP, systolic blood pressure; SFA, saturated fatty acid; TC, total cholesterol; TG, triglyceride; TNF-α, tumor necrosis factor alpha; VAT, visceral adipose tissue; VCAM1, vascular cell adhesion molecule 1; VLDL, very low-density lipoprotein; VS ratio, visceral to subcutaneous abdominal adipose.

[a] Comparisons between experimental (avocado) and control groups, ↓: reduction, ↑: increase, ↔: unchanged,

[b] Same clinical trial with different outcomes.

[c] Relative amount analyzed.

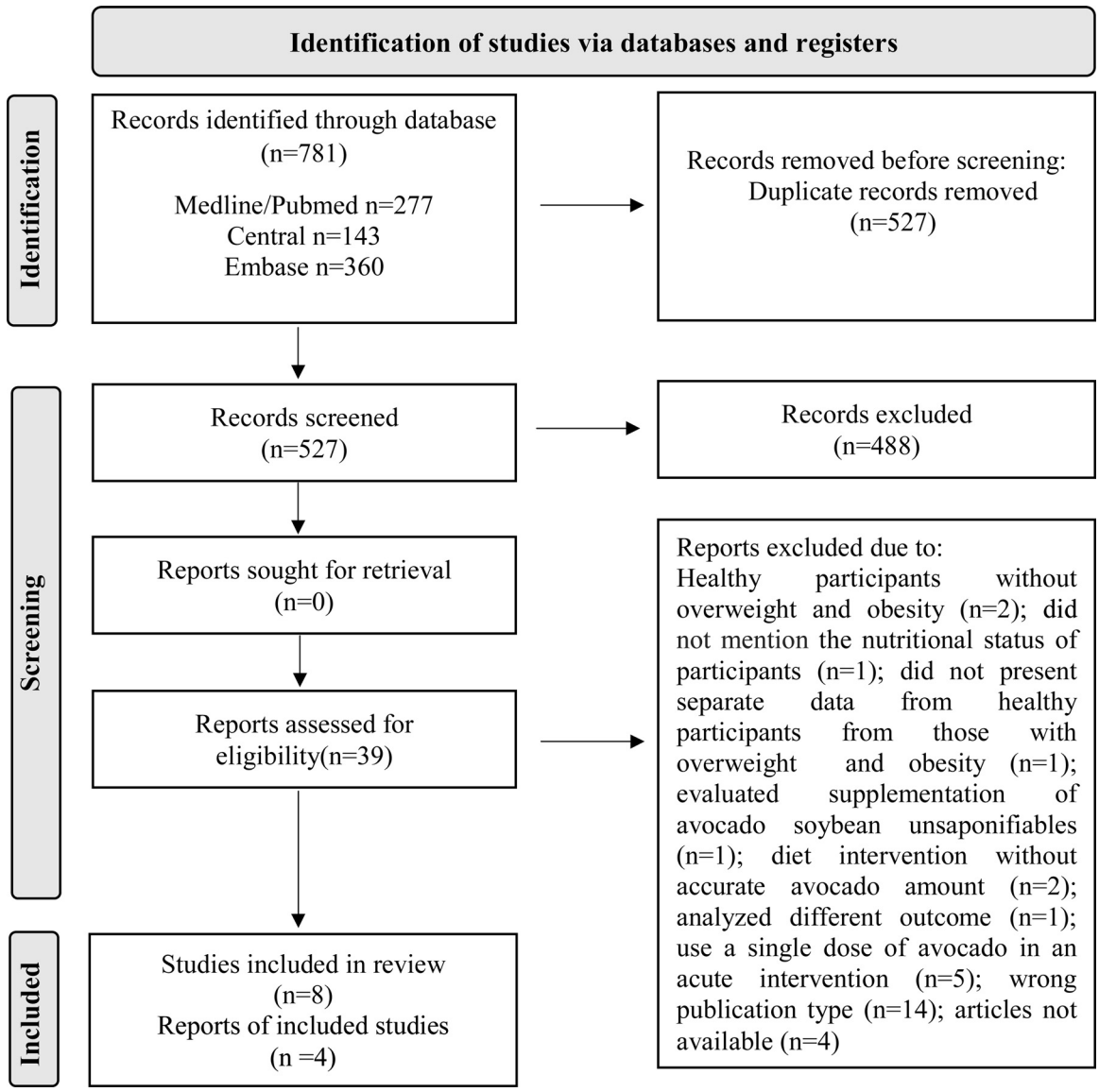

Fig. 1 – Selection process for article inclusion. Based on PRISMA diagram for the selection process of articles for inclusion ("The PRISMA 2020 statement: An updated guideline for reporting systematic reviews" [22]). Eight articles met eligibility requirements and were included in this systematic review and 4 were included for meta-analysis. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analyses.

3. Results

3.1. *Description of included studies and selection process of articles*

We retrieved 781 articles through searches of the MEDLINE/PubMed, EMBASE, and CENTRAL databases. After removing duplicates in Rayyan QCRY software, 527 titles remained. During title and abstract screening, 488 records were removed based on the initial exclusion criteria. Thirty-nine articles remained for full-text review and 31 articles were excluded.

The most common reasons for study exclusion were healthy participants without overweight or obesity (n = 2), did not mention the nutritional status of participants (n = 1), did not present separate data from healthy participants from those with overweight and obesity (n = 1), evaluated supplementation of avocado and soybean unsaponifiables (n = 1), diet intervention without exact avocado amount (n = 2), analyzed different outcome (n = 1), used a single dose of avocado in an acute intervention (n = 5), wrong publication type (n = 14), and articles not available (n = 4). Eight studies were included for data extraction and analysis (Fig. 1). From these, 4 studies presented data of primary outcomes (body weight, BMI, % fat mass, and/or VAT changes) and were incorporated into the meta-analysis. The characteristics of RCT studies of populations and the synthesis of interventions and their main results are shown in Table 3.

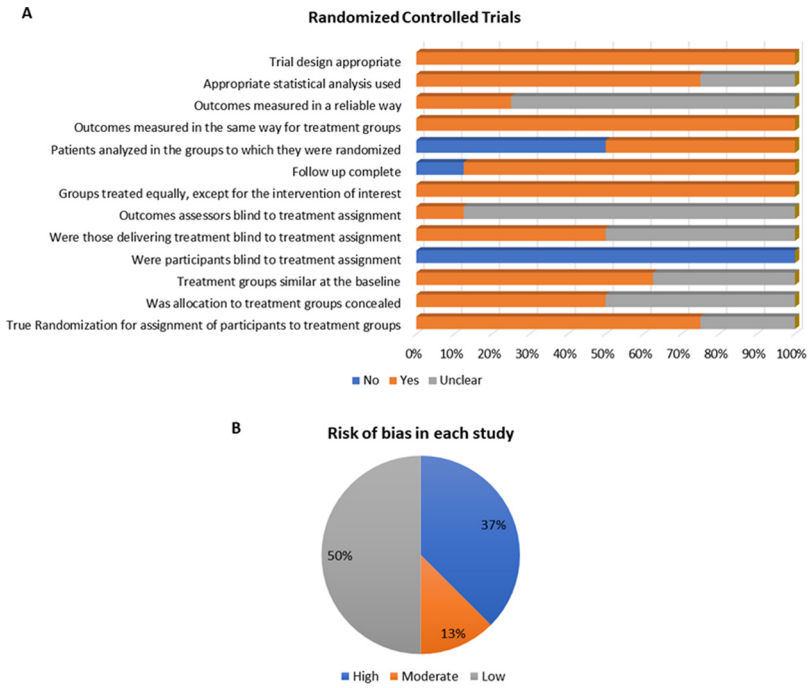

Fig. 2 – Risk of bias of each item assessed in the studies included in the systematic review and meta-analysis by the Joanna Briggs Institute Reviewer's Manual [26].

3.2. *Study characteristics*

Six randomized controlled parallel studies and 2 randomized crossover-controlled trials were included. The total sample consisted of 657 adults who mostly were female with a mean age of ≥34 and <45 years. The main condition presented was the presence of excess weight, and some participants also had dyslipidemia (Table 3).

3.3. *Parameters studied and type of intervention*

The Hass avocado type was reported in all interventions, except for 1 that did not describe the type of avocado [28]. Avocado consumption varied from 136 to 200 g/d. The intervention duration varied between 6 and 21 weeks. Five studies reported changes in anthropometric parameters (Table 3).

3.4. *Risk of bias within studies*

Fig. 2 summarizes the results of the risk of bias assessment. Most of the studies showed sufficient information and had a low (50%, n = 4) or moderate (13%, n = 1) risk of bias. Three studies were at high risk of bias [28,34,35] and just 1 of them analyzed the primary outcome. The intention-to-treat analysis was mentioned in just half of the articles [30–33], which justifies the prevalence of increased risk of bias on the item "Patients analyzed in the groups to which they were randomized." Only 2 studies mention the number and training of raters and whether the participants were blind to treatment assignment, which conferred the greater number of unclear and no answers. More details are in Supplementary Table S2.

3.5. *Evaluated outcomes*

3.5.1. *Anthropometric parameters*

The results of 2 studies [28,29] with 106 participants (n = 52 in the avocado group, n = 54 in the control group) were eligible for the data synthesis for body weight. Both interventions used a hypocaloric diet associated with avocado consumption. Five studies did not evaluate body weight [30,32-35], and 1 study did not provide numeric body weight values to compute the data [31]. The forest plot demonstrated no significant difference in body weight between avocado and control groups (SMD = 0.19, 95% confidence interval [CI], 0.19-0.57; P= .32; I^2 = 0%) (Fig. 3). An article with a high risk of bias was included in the analysis [28], but in the sensitivity analysis, it did not change the results found in the study.

The data synthesis for BMI and % body fat mass included 3 studies [28–30] with a total of 190 participants (n = 99 avocado group, n = 91 control group). Inspection of the forest plot revealed no significant differences in BMI between the avocado and control groups (SMD = 0.06; 95% CI, 0.22-0.35; P= 0.66; I^2 = 0%), neither in % body fat (SMD = 0.21; 95% CI, 0.08-0.50; P= .15; I^2 = 2%) (Fig. 3). The data synthesis for VAT involved two studies [29,32] with a total of 156 participants (n=76 avocado group, n=80 control group). The results showed no difference between avocado and control regarding the VAT (SMD = 0.08; 95% CI, 0.40-0.23; P= .60; I^2 = 0%) (Fig. 3).

A total of 4 studies [28-30, 32] involving 642 subjects (n = 326 avocado group, n = 316 control group) reported the effect in body weight, BMI, and/or VAT. When we pooled those results, the findings showed no reduction in body weight and composition compared to control (SMD = 0.09; 95% CI, 0.06-0.25; P= .25; I^2 = 0%) (Fig. 3). Sensitivity analysis gave no evi-

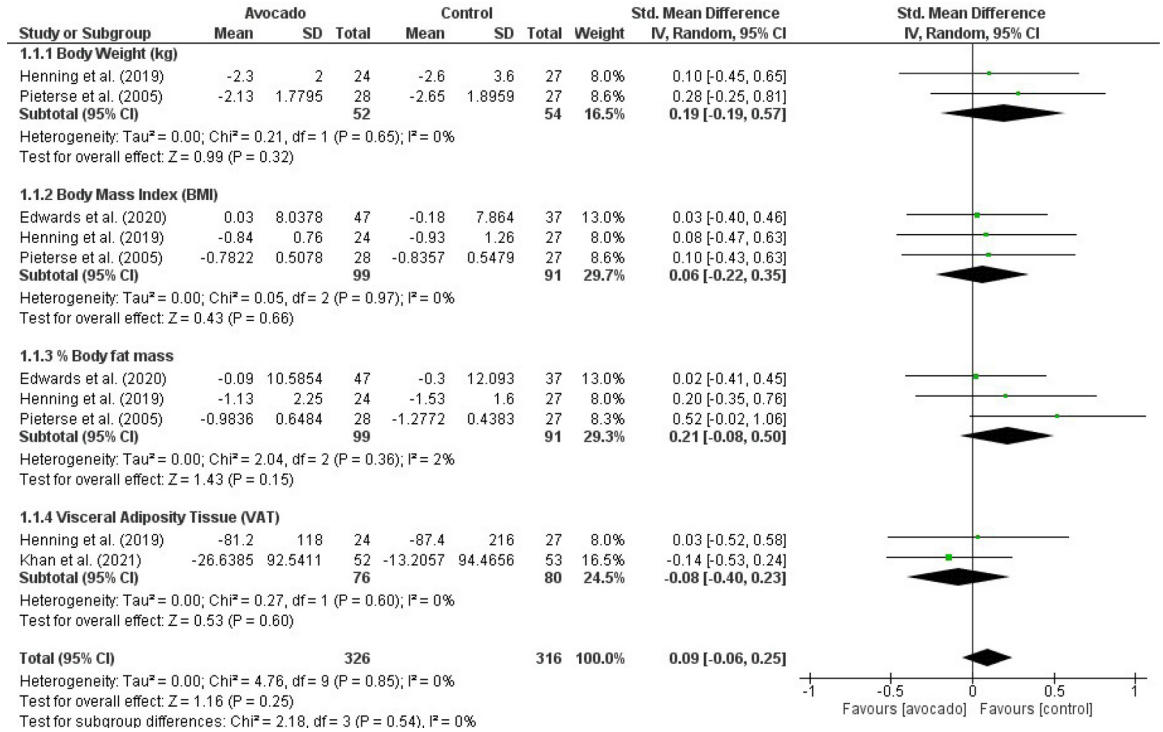

Fig. 3 – Forest plot of the effect size (95% CI) of avocado consumption on body weight (kg), BMI, % body fat mass, and VAT. Comparison between avocado intake and control groups. The results showed no significant differences in body weight, BMI, % body fat mass, and VAT. 95% CI, 95% confidence interval; BMI, body mass index; IV = independent variable, SD, standard deviation; Std, standard; VAT, visceral adiposity tissue.

dence of a significant impact on overall outcome in subgroup analysis by omitting certain trials.

Only 1 study investigated the subcutaneous abdominal adipose tissue and visceral to subcutaneous abdominal adipose ratio (VS ratio) [32], for this reason, it was not included in the meta-analysis. Khan et al. [32] found an unexpected result: the control group exhibited a greater reduction in subcutaneous abdominal adipose tissue (–54.5 ± 155.8 g [control] vs. 17.4 ± 155.1 g [treatment], $P = .017$) but increase in VS ratio (0.007 ± 0.047 [control] vs. 0.011 ± 0.044 (treatment), $P = .024$). An examination of the results based on sex revealed that, among females, the treatment group exhibited a greater reduction in VAT (1.6 ± 89.8 g [control] vs. –32.9 ± 81.6 g [treatment], $P = .021$) and VS ratio (0.01 ± 0.05 [control] vs. –0.01 ± 0.03 [treatment], $P = 0.001$). On the other hand, among males, there was no significant difference between these variables [32].

Most studies [28–30] mentioned that the participants in the compared groups were similar regarding their characteristics, which is considered an essential factor in the analysis. Moreover, all interventions were well-designed and had a reliance on a randomized-controlled study design to address the primary aims. Ultimately, the outcomes were measured in the same way concerning the instrument and scale used, procedures and instructions, and timing.

3.5.2. *Metabolic parameters*

Pieterse et al. [28] did not observe changes in total cholesterol (TC), low-density lipoprotein (LDL-C), triglycerides (TG), high-density lipoprotein (HDL-C), plasma fibrinogen, arterial compliance, systolic blood pressure, and diastolic blood pressure between experimental and control groups during the intervention with 200 g/d of avocado for 6 weeks. Similarly, there were no significant changes in the RCT [33], there were no group × time effects on TC ($P = .89$), HDL-C ($P = .30$), or TG ($P = .06$) concentrations in adults with excess body weight and obesity that consumed 175 g (males) or 140 g (females) of avocado for 12 weeks. Differently, Henning et al. [29] found that change in serum glucose over time (12 weeks) in the control group was significantly lower than that in the experimental group that consumed 1 avocado daily (136 g). Besides that, the serum triglyceride, cholesterol, and insulin did not change significantly in both groups.

Whereas a study that provided 3 cholesterol-lowering diets (6%-7% of saturated fatty acid [SFA]), with different sources and amounts of total fat for 5 weeks, showed that the inclusion of 1 fresh Hass avocado (136 g) (AV: 34% fat) per day in a healthy moderate-fat diet promotes significant improvement in lipid profile [34]. It was observed that the other 2 diets were a lower-fat diet (LF: 24% fat) and a moderate-fat diet (MF: 34% fat) that used mainly high oleic acid oils to match the fatty acid content of 1 avocado. The reduction in LDL-C (-10%), TC (-8%), TC/HDL-C (-4.9%), and LDL-C/ HDL-C (-6.6%) by the AV diet was significantly greater than the LF and MF diets. MF and AV diet decreased less HDL-C and more TG/HDL-C ($P < .05$) versus the LF diet. Also, the LF diet significantly increased TG (17.6%) and very-low-density lipoprotein (VLDL-C) (10.9%), whereas the MF and AV diets did not. The MF and AV diets decreased non-HDL-C (-5.1% and -9.3%, $P < .01$ for

both), but the LF diet did not. Furthermore, the AV diet elicited a more significant reduction in non-HDL-C (-9.3%, $P < .0001$) versus the MF diet (-5.1%, $P = .01$). The ratio of apolipoprotein B (apoB)/apolipoprotein A1 (apoA1) was decreased by the AV diet but was not affected by the MF and LF diets [34].

Fasting high-sensitivity C-reactive protein, insulin, glucose, homeostasis model assessment for insulin resistance (HOMA-IR) score, and systolic and diastolic blood pressure were not affected by any diet [34]. In a complementary study with the same sample and intervention [35], the authors analyzed if the avocado diet would lower oxidized LDL (oxLDL) concentrations and their impact on plasma antioxidants, oxidative stress markers, and proinflammatory genes expressions. They found that only the avocado diet significantly decreased plasma oxLDL and increased plasma lutein compared with the other diets (MF and LF). None of them significantly affected plasma retinol, α-tocopherol, γ-tocopherol, or δ-tocopherol [35].

In terms of inflammatory markers, there were no significant changes in proinflammatory genes of vascular cell adhesion molecule 1, intercellular adhesion molecule 1, monocyte chemoattractant protein-1, or interleukin-1B (IL-1B) mRNA levels between the diets in the PBMC samples from a random subset of participants (n = 21) [35]. Furthermore, Henning et al. [29] demonstrated that inflammatory markers (IL-6, monocyte chemoattractant protein-1, and tumor necrosis factor-alpha) and adipokines (leptin, adiponectin, resistin, and plasminogen activator inhibitor-1) were not changed significantly between groups. Khan et al. [32] found no differences between treatment (175-g male and 140-g female with fresh Hass avocado daily) and control groups in changes in HOMA-IR ($P = .100$), Matsuda index ($P = .285$), and the insulinogenic index ($P = .67$). Similarly, there were no changes among females or males.

4. Discussion

To our knowledge, this is the first systematic review and meta-analysis that evaluates the effect of Hass avocado intake on anthropometric parameters and body composition as a primary outcome in adults with excess weight. Our hypothesis that the intake of avocado pulp might be an excellent strategy to improve anthropometric parameters and consequently metabolic health was not confirmed by this study. Among the 8 articles found, 4 studies (n = 642) presented sufficient data to be included in meta-analyses, and the result showed no change in body weight and composition (i.e., body weight, BMI, % fat mass, and VAT) between avocado and control groups. However, the secondary outcomes showed some improvements in metabolic parameters, such as decreasing the concentration of TC, non-high-density lipoprotein, LDL, intermediate-density lipoprotein, VLDL-C, TG, ApoB, ApoB:ApoA1, TG:HDL [34], and oxLDL [35]. In addition, Thompson et al. [31] observed increased intake of monounsaturated fatty acids (MUFAs), pectin, fiber (meals with avocado), and serum lutein compared with the control groups studied. Overall, there were few studies, and not all studies showed an impact compared with control.

Avocado consumption has increased because it is considered a functional food rich in nutrients associated with health benefits [36]. Its nutritional composition is MUFAs, polyunsaturated fatty acids (PUFAs), folate, potassium, magnesium, phosphorus, several essential micronutrients and antioxidants such as vitamins C and E, and bioactive phytochemicals, for example, carotenoids [15].

Additionally, there are soluble and insoluble dietary fibers, recommended mainly for individuals under treatment of obesity [15,37]. Dietary fibers are associated with a lower body weight through various mechanisms, such as decreasing the total energy intake by increasing the volume of food that reduces the metabolizable energy density of foods [38]. Soluble fibers can also delay gastric emptying and slow or decrease fat and glucose absorption, which reduces caloric uptake [39]. Furthermore, because fiber contains large amounts of water, another possible explanation for its impact on weight loss is that it can increase the stomach's distention and trigger vagal afferent signals of fullness, leading to satiety [39]. Also, fatty acid products from fermentable dietary fibers can increase satiety by stimulating protein G receptors coupled to the colonocyte membrane, thus promoting secretion of appetite-suppressing peptides, such as cholecystokinin, YY peptide, and glucagon-like peptide [37,39].

Only 1 study in this systematic review evaluated satiety scores [29]. The authors did not find a significant change in the group that consumed avocado within a hypocaloric diet for 12 weeks, even with a significant weight loss. Hence, the improvement in this study's anthropometric parameters is probably not justified by satiety enhancement. However, some studies in the scientific literature have reported associations between a higher score of satiety after avocado intake and weight loss [40–42]. For example, Wien et al. [40] offered a lunch meal with and without approximately one-half of a Hass avocado to overweight and moderately obese adults. They concluded it could influence postingestive satiety over a subsequent 3- and 5-hour period. Given that the peak satisfaction was found to be within 3 hours of the lunch test meal, the authors suggested that avocado may be a good snack option for individuals in obesity treatment who typically consume large snacks between meals [40].

There has been little experimental work on adiposity despite avocado consumption being a marker of higher diet quality and potentially protecting against metabolic risk [15,17,35]. However, Khan et al. [32] revealed that consuming 1 daily meal with an avocado improved fat distribution, as indicated by a lower VAT and VS ratio among women. Because VAT accumulation surrounding internal organs such as the liver and heart is associated with chronic NCDs, the decrease of these parameters suggests that avocado intake improves a beneficial abdominal adiposity profile. Nonetheless, these benefits were observed only among females, emphasizing that the treatment effect is limited. Therefore, the development of more experimental research is crucial to characterize further the effects of daily avocado consumption on fat distribution [32].

The higher amount of fiber and MUFAs in avocado may be one of the explanations to contribute to VAT changes [17]. Dietary fiber intake is associated with lower VAT [43,44] and BMI and waist circumference reductions, independent of caloric

restriction [45]. Also, the degree of obesity and abdominal distribution of body fat have been negatively correlated with the MUFAs and n-3 PUFA contents of adipose tissue [46], indicating that the substitution of SFAs for MUFAs has a great potential to adjustment abdominal adipose distribution.

Pieterse et al. [28] and Henning et al. [29] also assessed whether there were differences between an energy-restricted diet with and without avocado intake because calorie restriction appears to be one of the most critical factors in weight loss and obesity treatment [11]. Although both articles did not find significant differences between groups, it is important to highlight that adding avocado daily in the dietary pattern did not hinder weight loss, especially if we consider that it is a moderate energy-dense food that impacts total calorie intake. Furthermore, the US and Canadian Adventist Health Study 2, which analyzed 55,407 normal-weight adults, observed that the odds of having overweight or obesity were reduced by 15% in high avocado consumers and 7% in low avocado consumers compared with those that do not have the habit of avocado consumption over an 11-year follow-up [19].

The findings showed that avocado intake did not promote weight gain, and, in general, some improvement in the metabolic profile was observed, which in the long run can help treat obesity [31,34,35]. In this manner, the most relevant secondary results found in this systematic review refer to the change in the blood lipid profile of adults with overweight or obesity after dietary consumption of avocado. Given the strong relationship between VAT and blood lipid concentrations, it is possible that the degree of excess adiposity can modulate negative changes in blood lipids [33]. The main source of avocado's fat is MUFAs (66.2%), such as palmitoleic and oleic acids, followed by linoleic and linolenic fatty acids (14.7%) [16,47]. However, it is necessary to highlight that saturated fat decreases during the maturation process, whereas the concentration of oleic acid increases [48].

Although low-fat diets are recommended, studies have indicated that changing the types of fat consumed can modify the risk of dyslipidemia [49,50]. Since saturated fat intake is currently relatively high among people, replacing these fatty acids with MUFAs and PUFAs has been associated with a decrease in the incidence of NCDs, especially cardiovascular diseases [51]. This occurs because of decreasing content of TC and LDL-C, which are associated with atherosclerosis [51], as seen in the results of 4 studies in this systematic review [29,33-35].

The linear structure of the carbon chain of SFAs allows them to carry greater amounts of cholesterol since it is overpacked in the center of lipoproteins [52]. Furthermore, the high consumption of SFAs is associated with reduced activity and expression of LDL receptor RNAm, impairing the clearance of LDL particles, and increased synthesis of enzymes such as hydroxymethylglutaryl coenzyme A reductase and lanosterol synthase, which are related to cholesterol synthesis [52].

A meta-analysis performed by Mensink [53] found that for every 1% of SFA calorie replacement by PUFAs or MUFAs, there is a reduction in plasma concentrations of TC, LDL-C, and ApoB. In general, the adequate consumption of PUFAs or MUFAs has shown positive and opposite effects to those observed with SFA on lipid metabolism. Although PUFAs induce greater lipid oxidation and decrease HDL-C when consumed in large quantities, their ingestion decreases plasma TG. Additionally, it causes LDL structure changes to reduce the cholesterol content of the particle. The mechanisms involved in this reduction are the decrease of the hepatic synthesis of VLDL-C and the production of LDL by maximizing its removal through the increase of LDL receptors. As a result, there is a decrease in blood viscosity and promotion of a greater endothelium relaxation. MUFAs, on the other hand, have the same effect on cholesterolemia without decreasing HDL-C and causing lipid oxidation [54]. Another component rich in avocado that may be crucial to improving lipid profile is the magnesium, 136 g of Hass avocado contains 39 mg of magnesium [55]. It is necessary for the activity of lecithin cholesterol acyltransferase and lipoprotein lipase, which lowers TG levels and raises HDL-C [56]. It can also help limit the enzymes promoting cholesterol biosynthesis [56].

Another metabolic benefit of including avocado in the dietary pattern is related to vascular health, inflammation, and oxidative stress [15,57]. Wang et al. [35] found that only the avocado diet significantly decreased plasma oxLDL regarding the other 2 diets (lower and moderate-fat diet). Inflammation and oxidative stress are interrelated and are involved mainly in the genesis of atherosclerosis [58]. OxLDL, formed by continuous exposure of LDL to agents that transform it into its oxidized form in the subendothelial layer, has a strong immunogenic [59] and inflammatory potential, with consequent induction of the release of cytokines, chemokines, and activation of T cells [60]. Also, serum C-reactive protein (CRP) concentration was also elevated during inflammatory conditions such as obesity, cardiovascular disease, and diabetes and has been correlated with BMI during weight loss [61–63].

Most likely, the fatty acid profile of Hass avocados is responsible for beneficial effects on inflammation and oxidative stress . Fatty acids play an important role in inflammatory processes through selective binding to toll-like receptors, responsible for recognizing molecular patterns associated with pathogens and stimulating inflammatory responses [64]. Although the exact mechanism has not yet been elucidated, it has been suggested that oleic acid may reduce the concentrations of inflammatory markers such as IL-6, CRP, and tumor necrosis factor-alpha, exerting anti-inflammatory and vascular protection properties [65,66]. In addition, avocados also contain lipophilic phytochemicals, including vitamins E and C, xanthophylls, carotenoids (lutein, zeaxanthin, and β-carotene), and sterols that have antioxidant and free radical elimination activities [49,67]. Combining vitamins C and E in the avocado composition is very advantageous because vitamin C recycles vitamin E to maintain circulatory antioxidant protection, which positively affects slowing atherosclerotic progression and lowering LDL-C oxidation [68]. Also, circulating xanthophylls carotenoids apparently reduce oxidized LDL-C and consequently detain progression of vascular damage [69].

Avocado's phenolic compounds, such as 140 mg gallic acid in one-half of a fruit, also reduce these conditions by increasing blood flow, maintaining arterial endothelial health, and inhibiting platelet aggregation [70,71]. The avocado also has a total antioxidant capacity of 600 μmol Trolox Equivalent (CRP) for 30 g or 1350 μmol CRP for one-half of a fruit [72]. Indeed, acutely, avocado can diminish the formation of reactive oxy-

gen species and lipid peroxidation and block the reduction of nitric oxide caused by foods rich in calories and saturated fat, such as hamburgers [73].

As to the effect of avocado intake on glucose and insulin outcomes, 3 studies found no significant difference in the concentrations of glucose, insulin, HOMA-IR, Matsuda index, and insulinogenic index [29,32,35]. Therefore, a longer duration of intervention with many individuals is necessary to observe metabolic benefits for insulin sensitivity following avocado consumption. However, this systematic review suggests that daily consumption of a meal including an avocado, a fruit rich in fatty acids, does not detrimentally affect insulin resistance or oral glucose tolerance among adults with excess weight.

A strong point of this study was the inclusion of controlled and RCTs. However, it is necessary to adduce some limitations, such as the wide variety in the sample size, avocado consumption, intervention period, and the dietary strategy used by studies that may have influenced the results. The sample size of each article may have masked a possible effect on the variables. Moreover, most participants were women and young adults. Therefore, further research that includes same number of male participants and a wider age range is necessary to understand the dietary intervention effects. As the prevalence of obesity continues to increase, effective strategies to control obesity and its comorbidities, including glucose and insulin response, and dyslipidemia are needed. Thus, future studies that analyze the role of precision nutrition in the benefits of consuming avocado over a long period and with a larger sample size are recommended due to its clinical relevance.

To conclude, this systematic review and meta-analysis summarize the information about the connection between chronic consumption of avocado and changes in anthropometric parameters and metabolic health in adults with excess weight. Findings of the meta-analysis showed that avocado consumption did not promote changes in body weight and composition between groups, also, data from RCTs look promising because avocado showed potential to improve lipid profile. However, further studies are needed to elucidate these effects. Finally, this study dispels the myth that avocado is fattening and should not be included in an energy-restricted diet, since it does not promote weight gain.

Declaration of Competing Interest

None.

CRediT authorship contribution statement'

Aline R. Conceição: Conceptualization, data curation, formal analysis, investigation, methodology, resources, software, validation, visualization, writing - original draft, writing - review and editing. **Gabriela M. Fraiz:** Conceptualization, data curation, formal analysis, investigation, methodology, resources, software, validation, visualization, writing - original draft, writing - review and editing. **Daniela M. U. P. Rocha:** Data curation, formal analysis, software, writing - review and editing. **Josefina Bressan:** Conceptualization, funding acquisition, project administration, supervision, validation, visualization, writing - review and editing.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.nutres.2022.03.005.

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