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Effect of Tart Cherry Juice Consumption on Body Composition and Anthropometric Measures: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

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ABSTRACT

The present systematic review and meta-analysis were accomplished to understand the effects of tart cherry juice consumption on body composition and anthropometric measures. Five databases were searched using relevant keywords from inception to January 2022. All clinical trials investigating the effect of tart cherry juice consumption on body weight (BW), body mass index (BMI), waist circumference (WC), fat mass (FM), fat-free mass (FFM), and percentage body fat (PBF) were included. Out of 441 citations, 6 trials that enrolled 126 subjects were included. Tart cherry juice consumption significantly did not reduce BW (weighted mean difference [WMD], −0.4 kg; 95% confidence interval [CI], −3.25 to 2.46; p = 0.789; GRADE = low), BMI (WMD, −0.07 kg/m^2; 95% CI, −0.89 to 0.74; p = 0.857; GRADE = low), FM (WMD, 0.21 kg; 95% CI, −1.83 to 2.25; p = 0.837; GRADE = low), FFM (WMD, −0.12 kg; 95% CI, −2.47 to 2.27; p = 0.919; GRADE = low), WC (WMD, 1.69 cm; 95% CI, −1.88 to 5.27; p = 0.353; GRADE = low), and PBF (WMD, 0.18%; 95% CI, −1.81 to −2.17; p = 0.858; GRADE = low). Overall, these data suggest that tart cherry juice consumption has no significant effect on BW, BMI, FM, FFM, WC, and PBF.

Keywords: Cherry extract; Body composition; Anthropometric measures; Meta-analysis

INTRODUCTION

Obesity has emerged as a major health issue for both individuals and societies around the world [1]. Worldwide, 41 million children and 2 billion adults are overweight or obese, according to the 2017 global nutrition report [2]. Quantitative indicators or indices of obesity

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Conflict of Interest
The authors declare that they have no competing interests.

Author Contributions
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and adiposity can be calculated in two ways: Simple measurements can be used to calculate anthropometric indices like the body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), and waist-to-hip ratio (WHR) [3]. Obesity has a significant negative impact on life expectancy and raises the risk of cardiovascular disease (CVD), type 2 diabetes, and a number of non-metabolic comorbidities like cirrhosis, depression, trouble sleeping, and some forms of cancer [4]. As a result, preventing and treating obesity is crucial to lowering the risk of chronic diseases [1]. Researchers are looking for a natural substance or extract that can help people stick to a diet that reduces calories and increases physical activity in order to improve energy balance [5].

Anthocyanins, flavonoids, flavanols, gallic acid equivalents, procyanidins, and phenolic acids are just a few of the phytochemicals found in Montmorency tart cherries (prunus cerasus) [6]. Tart cherries' polyphenols, which act as "free radical" scavengers and inhibit cyclooxygenase (COX) to a level comparable to that of non-steroidal anti-inflammatory drugs (NSAIDs), appear to have antioxidant and anti-inflammatory properties [7,8]. A growing body of research suggests that eating vegetables and fruits like tart cherries, which have anti-inflammatory and antioxidant properties, may reduce the risk of chronic diseases like obesity. These diseases are linked to oxidative stress and inflammation [9].

Some human studies reported conflicting results about the effect of tart cherry juice consumption on body weight (BW) and body composition. Some clinical trials reported a significant effect of tart cherry on body composition parameters [10], while other studies did not support such findings [9,11]. We are aware of no previous study that has summarized the effects of drinking tart cherry juice on BW. As a result, we set out to carry out a systematic review and meta-analysis of randomized controlled trials (RCTs) in order to determine whether or not adults' BW, BMI, WC, and body composition parameters were affected by drinking tart cherry juice.

MATERIALS AND METHODS

We presented this meta-analysis of the effects of cherry juice on weight and body composition in accordance with the Preferred Reporting Items of Systematic Reviews and Meta-Analysis (PRISMA) statement [12].

Search strategy

A systematic search of online medical databases, including PubMed/Medline, SCOPUS, Cochrane Library, and Google Scholar, was conducted until January 2022. We used applied search terms to find published related studies (**Supplementary Table 1**). We additionally hand-searched all the references of related clinical trials and reviews to ensure that we did not miss any potentially eligible trials. Data from unpublished or grey literature, such as conference abstracts, theses, and patents, was not included in the current meta-analysis.

Inclusion and exclusion criteria

The search terms and strategies were constructed according to the PICOS model [13]. We included studies that met the following inclusion criteria: 1) studies that were conducted on adults (≥ 18 years old); 2) were clinical trials investigating the effect of tart cherry juice consumption; 3) studies that assessed BW or/and BMI or/and WC or/and fat mass (FM) or/and fat-free mass (FFM) or/and percentage body fat (PBF) as outcome measures. Studies were

excluded: if they 1) were conducted on children, adolescents or pregnant women; 2) investigated any other intervention along with tart cherry juice; and 3) articles without any comparator control group. We resolved disagreements about the studies inclusion through discussion.

Data extraction

The following data were extracted with a standardized data collection form by 2 independent reviewers (MRA, FS): the first author's last name, country in which the study carried out, date of publication, study design, participants' mean age in both intervention and control groups, participants' gender, number of participants' in both groups, duration of intervention, participants' health status, mean ± standard deviation (SD) or changes in BW, BMI, WC, FM, and FFM and details about intervention and control diets. Any disagreements were resolved by a third independent investigator (AH), if necessary. WebPlotDigitizer software was used to estimate the amount of measures when they were reported in figures and charts in the original papers.

Quality assessment of studies

Evaluation of studies for bias We evaluated studies for bias using the revised Cochrane Risk of Bias Tool (Rob 2) [14]. We considered the following methodological domains: 1) random sequence generation, 2) allocation concealment, 3) blinding of participants and personnel, 4) blinding of outcome assessment, 5) incomplete outcome data, 6) selective reporting, and 7) other potential threats to validity. Studies were categorized into low risk of bias, high risk of bias, and some concerns, according to Cochrane Handbook recommendations. The trials received an overall quality rating based on bias domains: good (≤ 1/5 items were unknown, and none were high), fair (≤ 2/5 items were unclear or at least one high), and high risk of bias (≥ 2/5 items were high) (**Table 1**).

Statistical analysis

Mean differences ± SDs of BW, BMI, WC, FM, FFM, and PBF in the intervention and control groups were used to calculate the effect size as mean difference in changes. We used the appropriate formula: $SD_{difference}$ = Square Root $[(SD_{pre\text{-}treatment})^2 + (SD_{post\text{-}treatment})^2 - (2 \times R \times SD_{pre\text{-}treatment} \times SD_{post\text{-}treatment})]$, assuming a correlation coefficient (R) 0.8 as it is a conservative estimate for an expected range of 0-1, to convert the available statistical data into mean and SD if the studies did not report them [18]. When means (± SD) of outcome measures was not directly available and a standard error of the mean (SEM) was presented in place of SD, we converted it to SD using this formula: SD = SEM × √n, being "n" the number of subjects in each group. If medians and inter-quartile range were reported, mean and SD values were estimated using SD = interquartile range/1.35 (symmetrical data distribution) [19]. Random effects model by DerSimonian and Kacker [20] and Laird method was applied to take into account between-study heterogeneity. We did I^2 testing to quantify the magnitude of inter-study heterogeneity, with values greater than 50% as evidence of moderate to high heterogeneity. When there was a

Table 1. Risk of bias for randomized controlled trials, assessed according to the revised Cochrane Risk of Bias tool for randomized trials (RoB 2)

Publications	Year	Random Sequence Generation	Allocation concealment	Blinding of participants, personnel and outcome assessors	Incomplete outcome data	Selective outcome reporting	Other bias	Risk of bias
Chai et al. [15]	2018	L	S	L	L	L	L	Good
Desai et al. [11]	2018	L	S	L	L	L	L	Good
Martin et al. [9]	2018	L	S	L	L	L	L	Good
Martin and Coles [17]	2019	L	S	H	L	L	L	Fair
Johnson et al. [10]	2020	L	S	L	L	L	L	Good
Kimble et al. [16]	2021	L	S	L	L	L	L	Good

L, low risk of bias; H, high risk of bias; S, some concerns.

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significance between-study heterogeneity. To estimate the effect size of each study individually, a sensitivity analysis was performed. Any publication bias was investigated quantitatively measured using an Egger test. In case of detecting potential publication bias (p values less than 0.05). The analysis was carried out using Stata software, version 14 (Stata Corp., College Station, TX, USA). The p-values less than 0.05 were regarded to be statistically significant.

Grading the evidence

We used the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) tool in order to evaluate the overall certitude of the evidence for each outcome [21]. This tool sorts the evidence as high, moderate, low, or very low for each outcome. HSH and MRA, 2 pairs of authors, independently utilized the GRADE assessment and then consensus to reach a single result.

RESULTS

Study selection

The flow diagram of study selection is shown in **Figure 1**. After screening of 441 papers in our initial search, 15 relevant articles remained for further examination of full texts. Out of these articles, 9 studies were excluded because of the following reasons: irrelevant (n = 4), no placebo-controlled (n = 1), complex intervention (n = 1), did not report adequate data of outcomes (n = 2), conference abstracts (n = 1). Finally, six eligible trials were included in the current quantitative analysis [9-11,15-17].

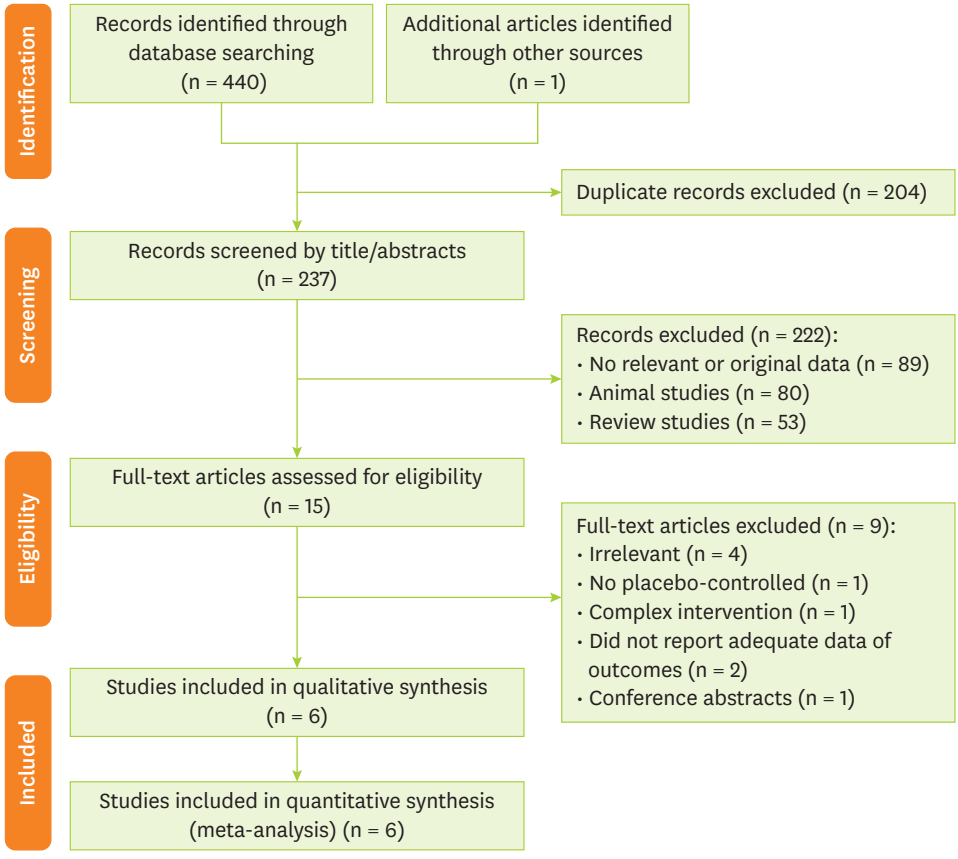

Figure 1. Flow chart of the number of studies identified and selected into the meta-analysis.

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Table 2. Demographic characteristics of the included studies

First author	Year	Location	Study design	Health status	Gender	Sample size	Duration (wk)	Mean age (yr)	Baseline BMI (kg/m²)	Intervention		Outcome
										Control group	Treatment group	
Chai et al. [15]	2018	USA	Randomized, single-blind, placebo-controlled, parallel trial	Healthy	Both	34	12	69.7	27.9	Placebo	68 mL tart cherry juice	BW/BMI
Desai et al. [11]	2018	United Kingdom	Randomized, single-blind, placebo-controlled, counterbalanced design, pre-exercise	Healthy	Both	11	3	30	24.43	Placebo	30 mL montmorency tart cherry juice	BW/BMI/ WC/FM/ FFM/PBF
Martin et al. [9]	2018	USA	Randomized, double-blind, placebo-controlled, cross-over	Healthy	Both	10	4	38.1	32.2	Placebo	240 mL tart cherry juice	BW/BMI/ FM/FFM
Martin and Coles [17]	2019	USA	Randomized, placebo-controlled, cross-over	Healthy	Both	26	4	41	31.3	Placebo	240 mL tart cherry juice	BW/BMI/ WC/FM/ FFM/PBF
Johnson et al. [10]	2020	USA	Randomized, single-blind, placebo-controlled, parallel trial	Metabolic syndrome	Both	19	12	36.7	33.9	Placebo	240 mL tart cherry juice	BW/BMI/ WC/FM
Kimble et al. [16]	2021	United Kingdom	Randomized, double-blind, placebo-controlled, parallel trial	Healthy people with a ≥ 1 risk factor for type 2 diabetes	Both	26	12	48	27.6	Placebo	60 mL tart montmorency cherries	BW/BMI/ FM/FFM/ PBF

BW, body weight; BMI, body mass index; WC, waist circumference; FM, fat mass; FFM, fat free mass; PBF, percentage body fat.

Study characteristics

The general characteristics of included articles are illustrated in **Table 2**. These papers were RCTs published between 2018 and 2021, and were conducted in the USA [9,10,15,17], the United Kingdom [11,16]. All studies had a parallel study design including a non-intervention group.

Overall, 126 participants, aged 30 to 69.7 years, were included in these studies. The duration of the studies ranged from 3 to 12 weeks. All studies included both genders. Participants were healthy [9,11,15,16], metabolic syndrome patients [10], and healthy people with a ≥ 1 risk factor for type 2 diabetes [16]. Also, tart cherry juice consumption was administrated in doses ranging from 30 mL/day [11] to 240 mL/day [10,17]. The shortest intervention period was 3 weeks [11] and the longest intervention period was 12 weeks [10,15,16]. Participants' BMI varied between 24.43 [11] to 33.9 kg/m² [10] at study baseline. BW and BMI were examined in 6 studies, WC in 3 studies [9,11,17], FFM and FM in 5 studies [9-11,16,17], and PBF in 3 studies [11,16,17].

Findings from the meta-analysis

Effects of tart cherry juice on BW and BMI

Pooling 6 effect sizes from 6 studies, including 126 participants, indicated that cherry juice significantly did not reduce BW (weighted mean difference [WMD], −0.4 kg; 95% confidence interval [CI], −3.25 to 2.46; p = 0.789) compared with control diet. There was not a significance between-study heterogeneity (I^2 = 0%; p = 0.994) (**Figure 2**). With regard to BMI, combining 6 effect sizes from 6 studies, including a total of 126 participants, we found no effect of tart cherry juice on BMI (WMD, −0.07 kg/m²; 95% CI, −0.89 to 0.74; p = 0.857) (**Figure 3**). No significance between-study heterogeneity was observed (I^2 = 0.0%; p = 0.99).

Effects of tart cherry juice on FM and FFM

Pooling 5 effect sizes from 5 publications, including 92 participants, we found tart cherry juice consumption had no significant effect on FM (WMD, 0.21 kg; 95% CI, −1.83 to 2.25; p = 0.837), with no significance between-study heterogeneity (I^2 = 0.0%; p = 0.982) (**Figure 4**).

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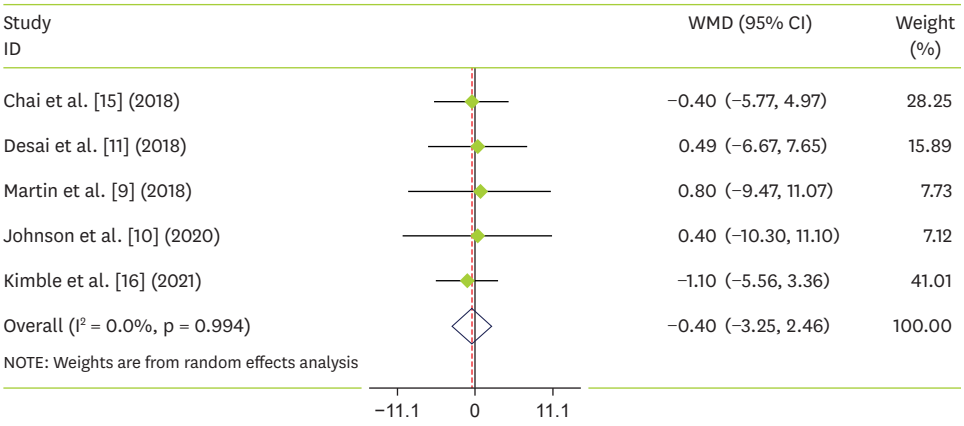

Figure 2. Forest plot detailing WMD and 95% CIs for the effect of tart cherry consumption on BW.
WMD, weighted mean difference; CI, confidence interval; BW, body weight.

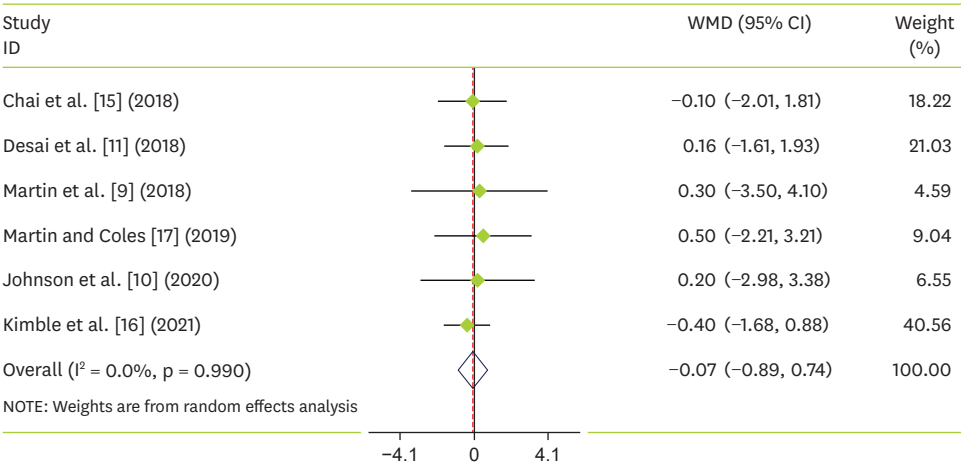

Figure 3. Forest plot detailing WMD and 95% CIs for the effect of tart cherry consumption on BMI.
WMD, weighted mean difference; CI, confidence interval; BMI, body mass index.

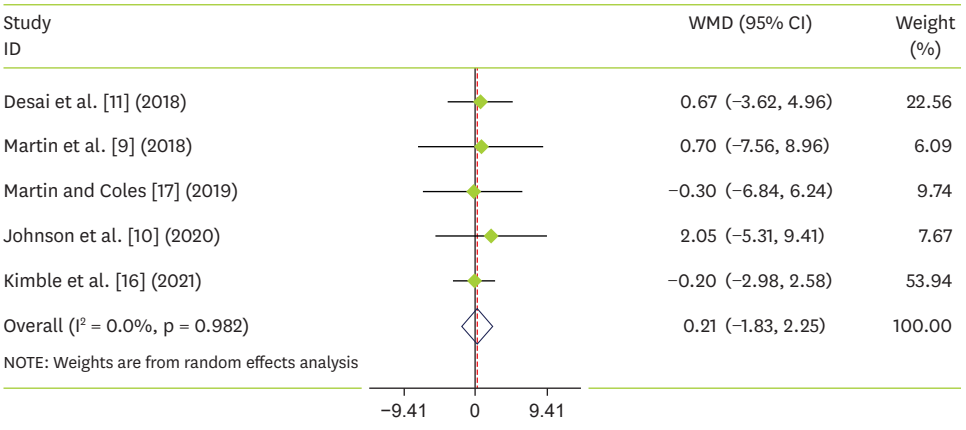

Figure 4. Forest plot detailing WMD and 95% CIs for the effect of tart cherry consumption on FM.
WMD, weighted mean difference; CI, confidence interval; FM, fat mass.

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About FFM, considering 5 effect sizes from five studies, including 92 participants, we found that tart cherry juice did not alter significantly FFM (WMD, −0.12 kg; 95% CI, −2.47 to 2.27; p = 0.919) (**Figure 5**). There was no significance between-study heterogeneity (I^2 = 0.0%; p = 0.865).

Effects of tart cherry juice on WC, and PBF

Based on 3 trials with 3 effect sizes, including a total of 56 subjects, we found that tart cherry juice consumption did not affect WC significantly (WMD, 1.69 cm; 95% CI, −1.88 to 5.27; p = 0.353; I^2 = 0.0%; P = 0.617) (**Figure 6**). About PBF pooling 3 effect sizes from 3 publications, including 64 participants, tart cherry juice had no significant effect on PBF (WMD, 0.18%; 95% CI, −1.81 to −2.17; p = 0.858; I^2 = 0.0%; p = 0.857) (**Figure 7**).

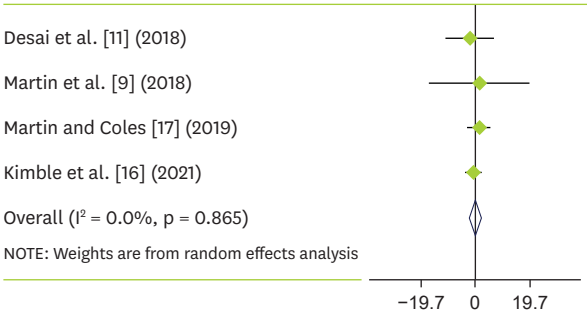

Figure 5. Forest plot detailing WMD and 95% CIs for the effect of tart cherry consumption on FFM.
WMD, weighted mean difference; CI, confidence interval; FFM, fat-free mass.

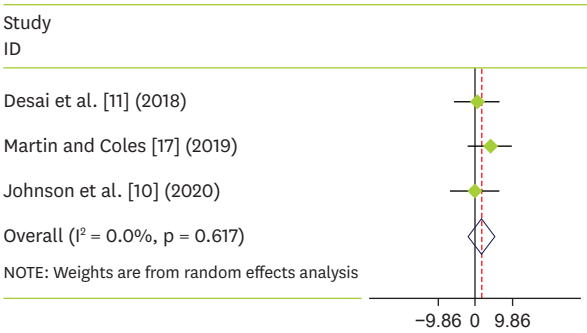

Figure 6. Forest plot detailing WMD and 95% CIs for the effect of tart cherry consumption on WC.
WMD, weighted mean difference; CI, confidence interval; WC, waist circumference.

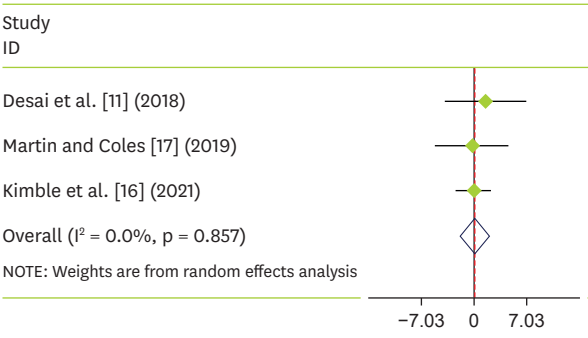

Figure 7. Forest plot detailing WMD and 95% CIs for the effect of tart cherry consumption on PBF.
WMD, weighted mean difference; CI, confidence interval; PBF, percentage body fat.

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Sensitivity analysis and publication bias

To detect the impact of a single trial on the pooled effect sizes, we removed each study from the analysis. The effect sizes for the influence of tart cherry juice on BW, BMI, FM, FFM, WC, and PBF were robust in the leave-one-out sensitivity analysis. Egger's weighted regression tests were conducted to find the publication bias. The results of Egger's test showed no publication bias for BW ($p = 0.473$), BMI ($p = 0.562$), FM ($p = 0.248$), FFM ($p = 0.935$), WC ($p = 0.353$), and PBF ($p = 0.599$).

Grading the evidence

The certainty of evidence was judged using the GRADE approach. The certainty of evidence was rated low for BW, BMI, FM, FFM, WC, and PBF due to downgrades for imprecision and indirectness (**Supplementary Table 2**).

DISCUSSION

In this systematic review and meta-analysis, we identified a total of 6 RCTs that evaluated tart cherry juice consumption effect and they reported data related to participants' anthropometric information after using tart cherry juice consumption in different doses from 30 to 240 mL per day. Tart cherry juice consumption has no significant effect on BW, BMI, and PBF. Despite claims from some studies that cherries are high in fiber, diets high in fiber are linked to weight loss [22]. In this way, fiber-rich foods increase satiety and help reduce overeating [23,24]. Cherries have a high dietary fiber content, as well as being low in sugar and calories, which can help to lose BW and reduce WC and generally reduce FM [22]. Nevertheless, in this study, tart cherry juice consumption did not impact WC and FM significantly, nor did it improve FFM. Based on a study by Vitale et al., they found that consuming tart cherry juice in athletes restored strength and improved their recovery, but there was no information reported about a decrease or increase in FM or FFM [6]. These results could be attributed to tart cherry juice's polyphenol content, which has many antioxidants and anti-inflammatory properties [16]. After exercise, tart cherry juice lessens muscle pain, accelerates strength recovery, and reduces blood markers of inflammation and oxidative stress [6].

According to the findings of the researchers, tart cherries have a lot of anthocyanins [25-27]. Studies report that the anthocyanin content of tart cherries is 27% to 200% higher than in sweet cherries [27,28]. The main characteristic of anthocyanins is their strong antioxidant activity since they can scavenge oxygen free radicals and other reactive species [25].

Anthocyanins therefore offer a potential tool for studying oxidative stress and related diseases [25]. Tart cherry-enriched diets, for example, are reported to reduce oxidative stress and inflammation in animal studies [29]. The results of the study of Desai et al. [11], on the effect of consuming tart cherry juice for 12 days on the rate of fat oxidation at rest and during exercise showed that tart cherry juice had no effect on human fat oxidation; therefore, people in this group did not need to consume tart cherry juice when exercising to improve cardiometabolic markers.

Additionally, anthocyanins are highly biologically active and low toxic to the human body, and so many researchers are interested in anthocyanins' benefits for human health as well as their uses in the prevention and treatment of chronic illnesses such as obesity [30,31]. In the past,

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obesity was only thought to be caused by too much energy storage. However, numerous studies have shown that obesity can also be caused by chronic low-grade inflammation of adipose tissue [30,32]. Chronic diseases linked to obesity may be facilitated by inflammation [31].

Lee et al. suggested a possible mechanism for the beneficial effect of anthocyanins on obesity and inflammation [32]. The receptors first detect overeating status and then activate various transcription factors such as nuclear factor-κB, interferon regulatory factor-3, and activator protein-1 for delivery to the nucleus and attach to the promoter region of the target genes [31]. Finally, inflammatory cytokines are expressed, leading to chronic inflammatory conditions in WAT fat cells [31,32]. Lee et al. [32] claimed that in such cases, the consumption of anthocyanins in the diet of the individual might prevent such events and have a positive impact on health. According to the animal study, a diet high in polyphenols and tart cherries was also linked to increased mRNA peroxisome proliferator-activated receptor (PPAR)-γ expression of genes that control adipogenesis, lipid metabolism, and glucose control in abdominal [33]. Subsequently, through sirtuin-1-mediated PPAR and PPAR-γ coactivator-1 activation, enhancing skeletal muscle insulin sensitization due to increased fat oxidation [34].

Our meta-analysis has some advantages. We had a precise, systematic literature search. Also, our study only included RCTs, the causal inference obtained from our study is strong. Statistical examinations showed no evidence of publication bias in our analyses.

Our meta-analysis has some limitations too that could be considered in future studies: 1) this study included participants with different characteristics, 2) different doses and concentrations of tart cherry juice were used in the selected studies, 3) the effect of tart cherry juice consumption on BW, BMI, FM, FFM, WC, and PBF not directly studied, 4) the insufficient mechanisms in the background of the metabolic effects of tart cherry juice on anthropometric indices. Therefore, it seems that more human studies are needed to properly understand the exact mechanism of tart cherry juice. Finally, there is a limitation for understanding the long-term effects.

In summary, the main conclusion of our meta-analysis is that tart cherry juice consumption have no significant effect on BW, BMI and PBF. We also found that tart cherry juice consumption does not have a significant effect on reducing WC and FM, nor does it increase FFM. However, the findings should be interpreted with caution, given the limitations of the available studies, and appropriate design clinical trials, especially in obese people and also athletes, are essential to ultimately assess the effectiveness of tart cherry juice.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1

Search syntax

Click here to view

Supplementary Table 2

GRADE evidence table for effect of tart cherry juice consumption on body composition and anthropometric measures

Click here to view

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