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ORIGINAL PAPER

A Prospective Non-Randomized Open-Label Comparative Study of The Effects of Matcha Tea on Overweight and Obese Individuals: A Pilot Observational Study

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Abstract
Matcha tea has been used as an adjunct in weight loss programs. The weight loss effects of matcha tea were evaluated in a prospective non-randomized open-label comparative study of overweight and obese individuals who followed a specified low-calorie diet (LCD) plan. A total of 40 participants were enrolled and assigned to either matcha tea or control groups. The matcha tea group followed a LCD plan and received matcha tea once daily, whereas the control group followed only the LCD diet plan. The study lasted 12 weeks. The main outcome measures included anthropometric measurements, fasting blood glucose, hemoglobin A1c (HbA1c), lipid profile, obesity-related hormone peptides, pro-inflammatory and anti-inflammatory cytokines, and oxidative stress biomarkers. Thirty-four participants had completed the study. The matcha tea and control groups showed significant reductions in body weight, body mass index, waist circumference, water content, minerals, and fat mass at week 12. The post-treatment body composition and anthropometric measurements were not significantly different between the two groups. The matcha tea group showed a potential increase in HDL-C, a potential decrease in blood glucose, and a potential increase in HbA1c. Furthermore, the study indicated a potential decrease in insulin and leptin levels, a potential increase in the activity of superoxide dismutase, and a potential decreased activity of glutathione peroxidase. IL-10 was increased by matcha tea consumption. The data suggest that matcha tea may have some potential effect on weight loss, along with anti-inflammatory properties. The findings of this study will be used to design a multicenter randomized clinical trial to examine the potential weight loss benefits of matcha tea.

Keywords Matcha tea · *Camellia sinensis* · Obesity · Inflammation · Hypocaloric diet · Oxidative stress

Abbreviations

BMI	Body mass index
GPx	Glutathione peroxidase
IL	Interleukin
LCD	Low-calorie diet
MCHC	Mean corpuscular hemoglobin concentration
SOD	Superoxide dismutase
TBARS	Thiobarbituric acid reactive substances
VCAM-1	Vascular cell adhesion molecule-1
WC	Waist circumference

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Introduction

Obesity is a global health issue that is dramatically increasing worldwide [1, 2]. In 2016, it was estimated that about 13% of the world's adult population are obese indicating that the prevalence of obesity has tripled since 1975 [2]. Obesity has been recognized as a major risk factor for many diseases, including cardiovascular, metabolic, pulmonary, and musculoskeletal diseases, as well as psychological conditions and certain types of cancer [1, 3]. Obesity is a chronic, complex and multifactorial disease [1]. It is manifested by an excessive accumulation of fat that results from an imbalance between energy intake and expenditure [1].

Weight loss can be achieved using several approaches, including lifestyle management [1], pharmacotherapeutic approaches [1], and surgical procedures [3]. Although adopting a healthy lifestyle, including healthier food choices and frequent physical activity can result in weight loss, but long-term maintenance is challenging [1]. On the other hand, prescribed weight loss medications may not be effective for all cases and their use is associated with adverse effects [1]. Hence, there is a growing interest to test other weight loss choices that are commonly used by the public such as herbal products and dietary supplements. It has been estimated that about 15% of adults have used herbal products or dietary supplements for weight loss [4]. For most of natural and herbal products, there is a lack of controlled clinical trials to demonstrate their safety and efficacy [4].

Tea [*Camellia sinensis* L. Kuntze (Theaceae)] is one of the most popular drinking beverages all over the world [5]. Green tea consumption is reported to have beneficial effects on health [5]. Matcha tea, a special type of green tea, is traditionally used in Japanese tea ceremonies [6]. It is different from green tea in terms of growing conditions and manufacturing processing [6]. Matcha tea is different, as well, from other forms of tea in the way of preparation and consumption. While in most types of green teas the water extract of the leaves is consumed, in matcha tea, however, water is added to the finely ground leaves powder and the whole leaves are consumed [6]. A number of clinical studies have demonstrated a positive correlation between green tea consumption that is rich in caffeine and catechins particularly (-)-epigallocatechin-3-gallate, and weight reduction and glucose control [7]. However, such studies are lacking for matcha tea, which has a potent antioxidant activity and is a rich source of caffeine [8]. Moreover, there is a worldwide increased interest in matcha tea as a healthy nutrient with promising applications in the field of functional food or nutraceuticals [8], including Jordan where a number of diet centers have started recently adding matcha tea to their low caloric diet plans.

The major goal of this study was to examine the efficacy of matcha tea administration on weight reduction in a prospective non-randomized open-label comparative study of overweight and obese individuals who were following a specified low-calorie diet (LCD) plan. The goal of the study was achieved via evaluation of the effects of matcha tea administration on anthropometric measurements, lipid profile, metabolic profile and glycemic control, obesity-related hormones, anti-inflammatory cytokines, and oxidative stress biomarkers. The procedure and the results of this pilot study will be utilized in designing a future larger, randomized controlled trial.

Materials and Methods

The material and methods section are reported as a supplementary online resource.

Results and Discussion

Over 100 people were screened for their eligibility and those who met the inclusion criteria were invited to participate in the study. Despite meeting the inclusion criteria, some individuals refused to participate, including those with a history of sensitivity to green tea, those who prefer to avoid herbal products, and women planning to become pregnant in the next three months. Therefore, 40 participants were enrolled and were allocated into either matcha tea or control groups (Fig. 1). There were 6 males and 14 females in each group. Participants in the matcha tea group were asked to follow a specified LCD plan in addition to an oral intake of a beverage of matcha tea [2 g in a cup of water once daily]. However, participants in the control group were asked to follow the same specified diet plan as in the study group (Fig. 1). Participants were required to visit the diet center once a week to ensure compliance with the diet plan and matcha tea consumption. On day 0, after fasting overnight, each volunteer undergoes blood and a body composition test. During the study, four female participants were excluded from the matcha tea group based on the following reasons: changing their living place, testing positive for COVID-19 with severe symptoms, being under quarantine due to family members testing positive for COVID-19, and not complying with the study protocol. Moreover, two female participants from the control group were excluded from the study due to failing to comply with the study protocol and refusing the blood withdrawal due to needle fear. Hence, a total of 34 participants completed the study (matcha tea group: 6 males and 10 females and control group: 6 males and 12 females). During the period of this pilot study, there were no reported adverse effects in the matcha tea group.

Demographics, Composition Analysis, and Anthropometric Measurements Baseline demographics, including gender and age as well as baseline anthropometric measurements including, weight, height, body mass index (BMI), and waist circumference (WC) showed no significant differences between the two groups ($p > 0.05$) (Table S1, Online Resource). A total of 27.8% of the control group and 37.5% of the matcha tea group were obese class I. Furthermore, 33.3% of the control group and 18.8% of the matcha tea group were obese class II. Likewise, 33.3% of the control

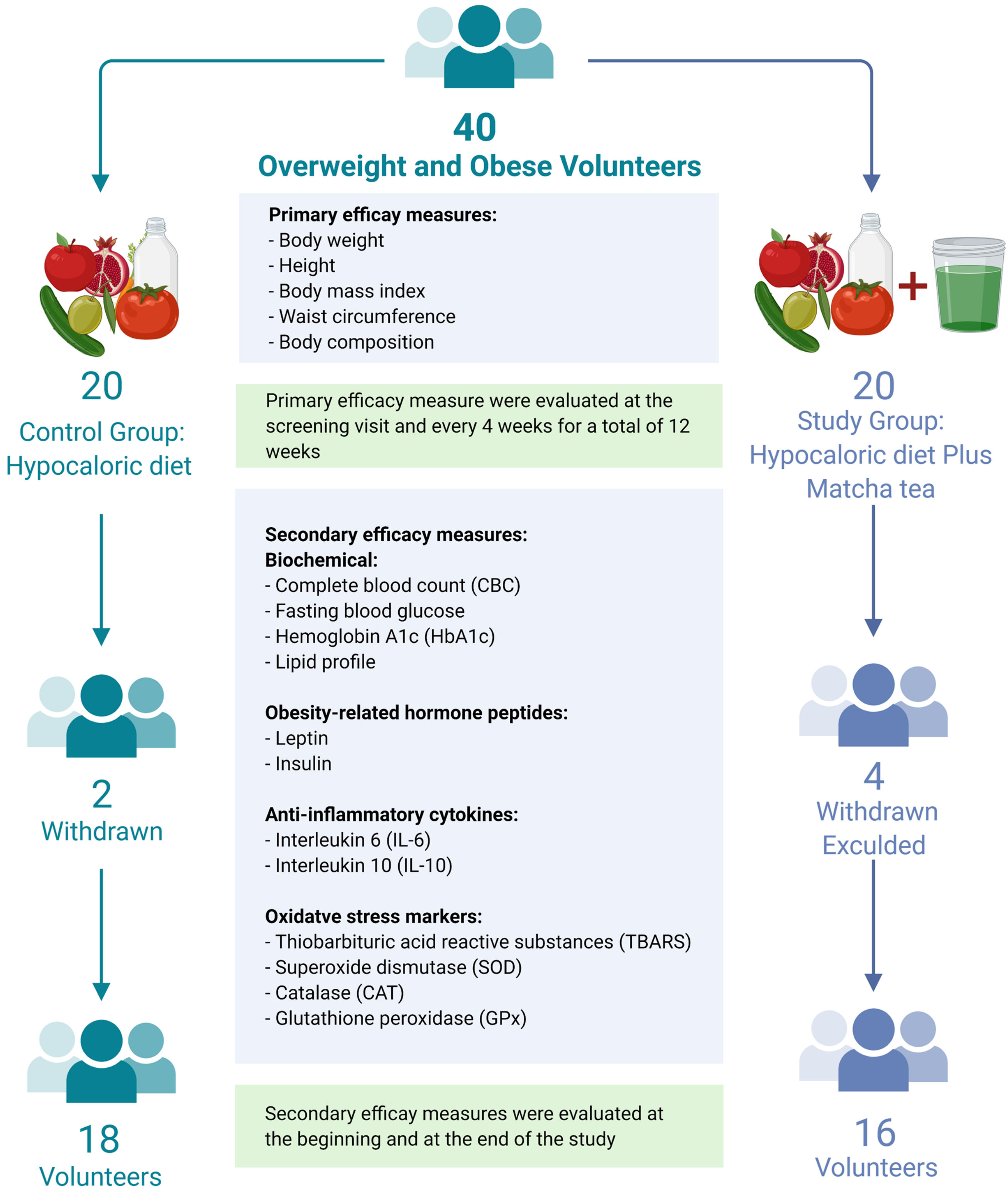

Fig. 1 Study design and methodology

group and 31.3% of the matcha tea group were classified as obese class III. Finally, overweight individuals make up 5.6 and 12.5% of the control and matcha tea groups, respectively. However, there was a significant difference between the two groups ($p < 0.05$) in terms of LDL-C and leptin levels (Table S1, Online Resource).

After 12 weeks of matcha tea intake, the body weight, BMI, and WC of the matcha tea group significantly decreased (Table 1). Moreover, the body content of water, protein, minerals, and fat mass were significantly reduced (Table 1). On the other hand, a significant difference was detected among all variables in the control group ($p < 0.05$), except for the protein content of the body (Table 1). Based on the between-group analysis of the post-treatment data, no significant differences were detected between the two groups for body weight, BMI, WC, water content, protein, minerals, or fat mass ($p > 0.05$) (Table 1). The results are consistent with previous studies on green tea for 12 weeks [9]. However, the protein content of the body was significantly reduced in participants who received a LCD plan plus matcha tea for 12 weeks compared to baseline protein content. This could be explained by the effect of matcha tea on increasing weight loss that affects all tissue types, leading not only to a reduction of fat mass but also decreased lean tissue [10]. Slentz et al. [11] reported a significant reduction in the weight and fat mass (abdomen, waist, hip circumference) for overweight participants who did not follow a diet but did an exercise at different intensities. Such reduction was increased as the physical activity increased [11].

Lipid Profile Analysis No statistically significant differences ($p > 0.05$) were detected in the lipid profile data after 12 weeks of matcha tea consumption (total cholesterol, triglycerides, LDL, or HDL) (Table 1). The level of HDL-C increased after 12 weeks of matcha tea in comparison to baseline levels, although the difference was not statistically significant. HDL-C exerts a protective effect on the development of cardiovascular diseases as it reverses the transport of cholesterol and exerts antioxidant, and anti-inflammatory effects [12]. The results are inconsistent with Yuan and colleagues [13] finding that green tea administration reduced total cholesterol and LDL-C [13]. The control group, on the other hand, showed a significant reduction in LDL levels ($p < 0.05$) (Table 1). This might be attributed by higher baseline levels of LDL-C in the control group as more participants were categorized as obese classes I and II and hence the effect on LDL-C was observed.

In the post-treatment data, there were no significant differences in lipid profiles between the two groups ($p > 0.05$) (Table 1).

Complete Blood Count with Differential Analysis In the matcha tea group, no statistically significant differences ($p > 0.05$) were detected in the complete blood count and differential data after 12 weeks of matcha tea consumption, except for mean corpuscular hemoglobin concentration (MCHC) and lymphocyte count. Where MCHC significantly decreased and lymphocyte count significantly increased (Table 1). Further studies are needed to examine the underlying cause of increased lymphocyte levels after matcha tea consumption in a larger clinical study. A previous study on rats revealed unaffected complete blood count by green tea consumption [14], inconsistent with the current human study. Measuring the levels of serum ferritin, total iron-binding capacity, and transferrin should be considered in future studies to confirm iron deficiency anemia. The control group, on the other hand, showed a significant reduction in platelet count (Table 1). A previous study revealed a decrease in platelet count, though not significant, in participants who followed a very low-calorie diet for eight weeks [15]. Platelets are the main players in the formation of thrombus as well as regulation of hemostasis. Low platelet count increased the risk of bleeding. However, it has been shown that it is important to assess the function of platelets when their count is low, especially for making clinical decisions [16]. An analysis of the between-group data revealed no significant differences between matcha tea and control groups in terms of complete blood count and differential ($p > 0.05$) except for basophils count which was significantly higher in the matcha tea group (Table 1). Basophils play a role in host defense against invading microorganisms, especially parasites, as well as for the development of allergic response [17]. Increased levels of basophils could be due to infection or hypothyroidism. Therefore, future studies should examine the levels of thyroid hormones as well as thyroid-stimulating hormones to withdraw conclusions. Of interest, EGCG decreased the expression of vascular cell adhesion molecule-1 (VCAM-1) [18]. VCAM-1 regulates the migration of basophils from blood to the tissue [19]. The reduced expression of VCAM-1, by EGCG, attenuated the migration of basophils from blood to tissues and this might explain the increased level of basophils in blood by matcha tea [20]. Therefore, examining the level and expression of VCAM-1 is of outstanding importance in future studies.

Metabolic Profile and Glycemic Control A significant reduction in the levels of fasting blood glucose was observed in the matcha tea group. However, the HbA1c level for the matcha tea group was unexpectedly increased from $5.0 \pm 0.4\%$ to $5.2 \pm 0.4\%$ ($p = 0.004$), although it remained within normal limits. In contrast, no significant differences were detected in blood glucose or HbA1c among those in the control group ($p > 0.05$) (Table 1). Liu and colleagues [21] suggested, in their meta-analysis, that green tea reduced fasting glucose as well as HbA1c [21]. The increased HbA1c in the current study could be due to lower hemoglobin levels that affect HbA1c at a given fasting glucose [22]. The effect of matcha tea on HbA1c should be studied longitudinally for longer durations to support the current argument. Furthermore, the level of insulin was reduced after 12 weeks of matcha tea consumption, although statistical analysis did not detect a

Table 1 Within-group body composition, anthropometric, and biochemical measurements data at baseline and after 12 weeks

Variable	Matcha tea ($n=16$)			Control ($n=18$)			Post-treatment *p*-value
	Baseline	After 12 weeks	*p*-value	Baseline	After 12 weeks	*p*-value	
Body composition and anthropometric measurements							
Weight, kg	97.4 (22.9)	86.8 (20.3)	**< 0.0001**	100.6 (19.4)	90.3 (17.6)	**< 0.0001**	0.600
Body mass index, kg/m^2	35.7 (5.5)	31.8 (4.7)	**< 0.0001**	36.9 (4.4)	33.2 (4.3)	**< 0.0001**	0.386
Waist circumference, cm	114.3 (16.4)	103.7 (16.1)	**< 0.0001**	116.4 (13.2)	104.9 (12.1)	**< 0.0001**	0.800
Water, L	39.4 (9.9)	38.1 (9.4)	**0.002**	40.4 (9.2)	39.2 (9.2)	**0.002**	0.738
Protein, kg	10.4 (2.8)	10.2 (2.6)	**0.014**	10.3 (2.6)	10.2 (2.5)	0.263	0.991
Minerals, kg	4.1 (1.1)	3.8 (1.0)	**0.001**	4.5 (1.2)	4.2 (1.1)	**< 0.0001**	0.286
Fat mass, kg	43.4 (11.9)	34.7 (10.7)	**< 0.0001**	45.3 (10.3)	36.7 (9.6)	**< 0.0001**	0.568
Lipid profile of study participants							
Total cholesterol, mg/dL	176.6 (39.2)	175.6 (39.6)	0.817	194.6 (28.3)	183.4 (25.5)	0.107	0.490
Triglycerides, mg/dL	115.4 (77.4)	101.2 (42.7)	0.265	101.9 (32.5)	99.8 (38.1)	0.717	0.920
Low-density lipoprotein cholesterol, mg/dL	113.5 (34.8)	112.4 (35.1)	0.753	136.3 (26.6)	125.3 (24.9)	**0.047**	0.221
High-density lipoprotein cholesterol, mg/dL	43.9 (13.1)	46.1 (11.3)	0.105	41.3 (9.5)	41.4 (7.5)	0.980	0.155
Complete blood count with the differential of study participants							
Red blood cells, million/mm^3	5.1 (0.7)	5.0 (0.7)	0.519	5.0 (0.5)	5.0 (0.6)	0.722	0.961
Hemoglobin, g/dL	14.3 (1.9)	13.7 (1.9)	0.065	13.7 (2.6)	13.7 (2.3)	0.810	0.730
Hematocrit, %	41.5 (4.8)	41.6 (5.3)	0.877	40.6 (6.7)	41.0 (6.0)	0.526	0.748
Mean corpuscular volume, fL	80.3 (10.1)	83.2 (5.4)	0.233	81.7 (8.7)	81.7 (7.8)	0.925	0.534
Mean corpuscular hemoglobin, pg	28.4 (2.7)	27.8 (2.2)	0.060	27.3 (3.7)	27.4 (3.4)	0.774	0.647
Mean corpuscular hemoglobin concentration, %	34.3 (1.3)	33.5 (0.7)	**0.025**	33.5 (1.4)	33.4 (1.1)	0.466	0.747
Red cell distribution width, %	14.1 (1.7)	14.2 (1.4)	0.656	14.6 (2.1)	15.0 (2.6)	0.104	0.260
White blood cells, thousand/mm^3	7.6 (1.7)	7.2 (1.4)	0.386	7.1 (2.0)	6.9 (1.7)	0.655	0.610
Neutrophils, cells/mm^3	58.2 (11.4)	55.3 (6.3)	0.113	58.8 (7.2)	54.2 (7.9)	0.065	0.648
Lymphocytes, cells/mm^3	32.4 (9.4)	35.7 (5.7)	**0.046**	32.2 (6.7)	37.2 (7.7)	0.052	0.515
Monocytes, cells/mm^3	7.1 (1.8)	6.7 (1.3)	0.383	6.8 (1.8)	6.6 (1.4)	0.675	0.867
Eosinophils, cells/mm^3	2.1 (1.9)	1.8 (1.5)	0.352	1.9 (1.6)	1.9 (1.7)	0.816	0.889
Basophils, cells/mm^3	0.7 (2.0)	0.6 (0.6)	0.827	0.2 (0.4)	0.1 (0.3)	0.668	**0.012**
Platelets, thousand/mm^3	288.0 (59.2)	276.8 (42.0)	0.205	314.4 (103.3)	286.9 (89.0)	**0.009**	0.682
Mean platelet volume, fL	9.0 (1.2)	9.0 (0.8)	0.718	9.2 (1.3)	8.9 (0.9)	0.262	0.839
Metabolic profile							
Fasting blood glucose, mg/dL	91.0 (9.9)	85.2 (9.2)	**0.004**	88.1 (13.2)	83.8 (8.5)	0.211	0.659
Glycemic control							
Hemoglobin A1c, %	5.0 (0.4)	5.2 (0.4)	**0.004**	5.1 (0.4)	5.2 (0.2)	0.134	0.845
Obesity-related hormones							
Insulin, mIU/L	13.8 (8.9)	11.3 (7.8)	0.163	10.2 (6.9)	10.7 (4.3)	0.698	0.785
Leptin, ng/mL	3.9 (1.7)	3.0 (1.2)	0.079	2.3 (1.1)	2.0 (0.8)	0.285	**0.005**
Anti-inflammatory cytokines							
Interleukin-6, pg/mL	5.2 (2.6)	5.1 (3.0)	0.761	5.4 (3.0)	7.2 (6.5)	0.152	0.236
Interleukin-10, pg/mL	8.0 (0.8)	10.2 (0.7)	< 0.0001	7.8 (1.3)	7.7 (1.30)	0.589	< 0.0001
Oxidative stress biomarkers							
Superoxide dismutase, inhibition %	63.03 (17.8)	72.0 (11.8)	0.086	66.6 (11.5)	73.7 (9.0)	0.108	0.644
Catalase, nmol/min/mL	22.6 (9.7)	24.7 (12.0)	0.524	19.8 (8.8)	23.4 (11.7)	0.305	0.755
Thiobarbituric acid reactive substances, μM	115.4 (32.0)	107.3 (32.3)	0.482	112.5 (18.3)	96.6 (21.6)	**0.030**	0.269
Glutathione peroxidase, nmol/min/mL	8.8 (5.0)	6.4 (1.4)	0.098	9.3 (4.2)	8.5 (4.4)	0.367	0.168

Data are presented as a mean with a standard deviation in parenthesis. Bold values indicate significant differences ($p < 0.05$)

significant difference. Thus, this suggests that the increase in HbA1c was not caused by matcha tea. The previous meta-analysis showed a significant reduction in insulin by green tea [21]. Increasing the number of enrolled participants is needed in future studies. An analysis of the between-group data indicated that there were no significant differences between matcha tea and control groups in terms of blood glucose and HbA1c levels ($p > 0.05$) (Table 1).

Obesity-Related Hormones Neither the matcha tea nor control groups showed any significant differences in insulin and leptin levels ($p > 0.05$) (Table 1). Matcha tea consumption in addition to a LCD for 12 weeks reduced leptin levels, though it did not reach a significant level ($p > 0.05$). However, matcha tea administration for 12 weeks resulted in a higher leptin concentration compared to control. The reason for this could be that participants who consumed match tea already had high levels of leptin at baseline. Auvichayapat and colleagues [23] showed that leptin levels were reduced by supplementation with green tea in obese participants in a randomized clinical trial [23]. A previous study proposed that EGCG and theaflavins of tea polyphenols suppress the gene expression of fatty acid synthase [24]. However, there are other determinants of the concentration of leptin, such as ghrelin and resistin, that should be examined in future studies. The between-group data showed that there was a significant difference in leptin levels between the matcha tea group (3.0 ± 1.2 ng/mL) and the control group (2.0 ± 0.8 ng/mL) with a p-value of 0.005 (Table 1).

Anti-Inflammatory Cytokines Interleukin (IL)-6 possesses pro- and anti-inflammatory properties [25]. In within-group analysis, the matcha tea group showed no significant differences in the levels of the anti-inflammatory cytokine IL-6 ($p = 0.761$) after matcha tea consumption. Previous studies revealed that green tea decreased the level of IL-6 [26]. A future study with a larger matcha tea dosage or a larger sample size may confirm the beneficial effects of matcha tea on lowering the levels of IL-6. However, a significant increase was observed in the IL-10 levels (Table 1). IL-10 is a potent anti-inflammatory cytokine as it inhibits the synthesis of several inflammatory mediators such as TNF-α, GM-CSF, IL-5 [27], IFN-γ, IL-2, and IL-4 [28]. Consistent with the current finding, a previous study showed that green tea increased the level of IL-10 [26]. Nevertheless, no significant differences were observed in the levels of IL-6 or IL-10 among the control group (Table 1). In the post-treatment data, the level of IL-10 was significantly higher in the matcha tea group compared to the control group (Table 1).

Oxidative Stress Biomarkers Oxidative stress is a phenomenon caused by an imbalance between the production of reactive species and accumulation in cells and tissues, and the ability of a biological system to detoxify these reactive products [29]. The levels of oxidative stress enzymes, superoxide dismutase (SOD), catalase, or glutathione peroxidase (GPx), were not significantly different between groups or within groups, except for thiobarbituric acid reactive substances (TBARS), which was significantly decreased from 112.5 ± 18.3 to 96.6 ± 21.6 μM, $p = 0.003$ (Table 1). However, the study showed an increased activity of SOD and decreased activity of GPx by matcha tea consumption for 12 weeks in comparison to baseline levels. The increased activity of SOD is a compensatory mechanism for the increased oxidative stress. A previous study showed that the consumption of green tea did not affect the serum levels of GPx and catalase activities [30]. However, in the current study, the activity of GPx was measured rather than its level. Another study on rats showed that green tea increased SOD activity [31]. Moreover, healthy women who consumed green tea extract had reduced levels of TBARS [32]. The variations in the results could be due to the dose differences of consumed matcha tea or the concentration of antioxidants in matcha tea itself that is affected by the storage conditions. Future studies should examine the activity of other antioxidant enzymes such as glutathione reductase. TBARS decreased significantly within the control group, and this could be due to the significant reduction of LDL levels. It has been shown that TBARS concentration is correlated with the levels of cholesterol and LDL-C in plasma [33]. In addition, it might be due to the increased levels of smoking in the matcha group than in the control group which could result in an oxidant/antioxidant imbalance as was shown previously, where TBARS levels were significantly higher ($p < 0.05$) in smokers than in nonsmokers [34]. It was shown in another study that cigarette smoking increased oxidative stress, affecting lipid peroxidation and diminishing both enzymatic and non-enzymatic antioxidant status that reduce SOD, catalase, and GPx [35].

Endpoints Percentage Change Percentage changes between the two groups of all data were analyzed (Fig. 2 and Table S2, Online Resource). There was a significant difference between matcha and control groups in terms of percentage insulin concentration change ($p = 0.024$). The percentage reduction in insulin reached 16.5% in the matcha group. However, the control group demonstrated a percentage increase of 25.9%. Regarding the anti-inflammatory cytokines, there was a significant difference between matcha and control groups in terms of percentage IL-10 concentration change ($p < 0.0001$). The percentage increase in IL-10 reached 27.7% in the matcha group. However, the control group demonstrated a percentage reduction of 1.0%. Moreover, IL-6 demonstrated a decrease of 0.5% in the matcha group and an increase of 34.2% in the control group, but their changes were not statistically significant ($p = 0.056$).

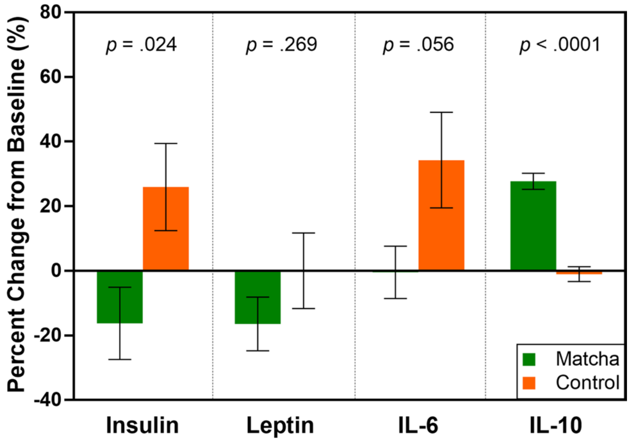

Fig. 2 Percentage change from baseline for the levels of insulin, leptin, IL-6 and IL-10 of study participants

There are some limitations to this study, such as (1) The small sample size as this is a pilot study, a larger-scale trial should be conducted. (2) Restrictions and lockdowns associated with COVID-19 affected participant compliance during the study. (3) The lack of regular follow-up with the participants during the period of the study to identify trends in biochemical data and other obesity-related hormones. (4) Liver function tests were not performed to assess the effect of matcha tea on the liver. (5) Lack of bioavailability and pharmacokinetics analysis of matcha components in plasma. (6) Randomization of participants was not implemented. Nevertheless, all the limitations of this study, as well as its design, measures, procedures, recruitment criteria, and operational strategies will be taken into account in designing a future randomized controlled trial.

Conclusion

This is a pilot study designed to shed light on the effects of matcha tea on overweight and obesity. Our findings suggest that matcha tea can be beneficial for weight loss. Matcha tea is considered a functional food and its consumption has been linked to an anti-obesity effect. Consequently, matcha tea can be viewed as a healthier nutraceutical choice that provides multiple health benefits to the human body. As a result, a thorough investigation of the chemical composition of matcha tea, *in vitro* studies, *in vivo* clinical trials, as well as animal studies are needed to confirm the positive effects of matcha tea. A deeper investigation of the bioavailability and pharmacokinetics of matcha tea components in humans is also warranted.

Considering the findings of this study, a future large-scale randomized controlled study is recommended. The study should be a randomized, multicenter study where different doses of matcha tea should be tested for at least 24 weeks. Moreover, the future study should include participants with BMI $\geq$ 30 kg/m^2. Secondary efficacy measures should be evaluated monthly and include, in addition to those in the pilot study, the following: hemoglobin, ghrelin, resistin, adiponectin, TNF-α, IL-5, IL-2, IL-4, GPx, glutathione reductase levels, liver function tests, heart rate, systolic and diastolic blood pressure. Moreover, pharmacokinetics profiling of the main components of matcha tea, functional studies on gastrointestinal motility and basal metabolic rate are highly recommended.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11130-022-00998-9.

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Data Availability All data generated during this study are included in this published article and its Online Resource files.

Declarations

Ethics Approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of King Abdullah University Hospital affiliated with the Jordan University of Science and Technology (Date 4/10/2020/No. 8/135/2020).

Consent to Participate Informed consent was obtained from all individual participants included in the study.

Consent to Publish Not applicable.

Conflicts of Interest The authors have no competing interests to declare that are relevant to the content of this article.

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