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Effects of Green Tea Extract on Ox-LDL and Homocysteine Levels after Resistance Exercise in Obese Men

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ABSTRACT

Introduction: Green tea is a well-known source of polyphenol catechins, which possess strong antioxidant properties. However, the impact of green tea polyphenol catechins on biological markers of atherosclerosis, namely oxidized low-density lipoprotein (ox-LDL) and homocysteine (Hcy), following resistance exercise (RE), has not been studied in obese individuals.

Methods: In this study, ten obese untrained men (age 43-45 y, BMI 32-33) participated voluntarily. They were randomly assigned to receive either green tea extract (GTE) capsules (two capsules of 500 mg per day) or placebo (PL) capsules (two capsules of 500 mg per day maltodextrin) in a double-blind, placebo-controlled crossover design. The supplementation period lasted for two weeks, followed by a two-week washout period. Afterward, the participants performed a RE protocol at 75% of their one-repetition maximum (1RM). Blood samples were collected before and after the RE session to measure the serum concentrations of Hcy and ox-LDL.

Results: In the placebo condition, there was a significant increase in serum Hcy and ox-LDL levels from pre- to post-RE. However, GTE supplementation mitigated the exercise-induced rise in serum Hcy and ox-LDL concentrations in obese men.

Conclusion: These findings suggest that a two-week supplementation of GTE may offer protection against exercise-induced elevation of Hcy and ox-LDL levels in obese men.

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Introduction

In today's world, obesity has become a significant health concern due to physical inactivity and excessive energy intake, leading to abnormal accumulation of fat in adipose tissue. This condition poses a major threat to human health [1]. Obesity can result in oxidative stress, characterized by an increase in the production of reactive oxygen and nitrogen species (ROS, RNS) and a decrease in antioxidant levels. Oxidative stress induced by obesity is primarily attributed to the oxidation of low-density lipoprotein (LDL) [2]. This oxidation is associated with endothelial dysfunction, atherosclerosis, and cardiovascular disease (CVD) [3]. Oxidized low-density lipoprotein (ox-LDL) serves as a reliable clinical biomarker for oxidative stress [4] and is considered a risk factor for CVD [5]. Previous studies have demonstrated that ox-LDL plays a crucial role in the initiation and progression of atherosclerosis [6]. Macrophages' scavenger receptors detect the produced ox-LDL, leading to the uptake of a large amount of cholesterol by these cells. Consequently, macrophages transform into foam cells as a result of this process [7, 8]. Therefore, preventing LDL oxidation may be the initial step in inhibiting their binding and accumulation by macrophages, thereby preventing their transformation into foam cells.

Apart from ox-LDL, homocysteine (Hcy) is another risk factor for the development of atherosclerosis. Hcy is an amino acid containing a thiol group and is produced during methionine metabolism in the liver [9]. Increased Hcy levels can be influenced by various physiological, genetic, and nutritional factors [10]. Hcy has been implicated in endothelial dysfunction through several mechanisms, including increased production of pro-inflammatory cytokines, impaired vasodilation, platelet accumulation, and elevated oxidative stress [11]. Additionally, Hcy has been shown to contribute to the oxidation of LDL and the production of ox-LDL [12]. Elevated Hcy levels have also been associated with reduced physical performance in

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adults and may play a role in morphological changes in skeletal muscle [13].

In recent years, numerous studies have indicated that plasma levels of Hcy increase following acute exercise [14, 15]. Previous research has observed an elevation in Hcy levels after acute circuit resistance exercise (RE) at 40% of one repetition maximum (1RM) in overweight women [16] as well as after acute circuit RE at 35% of 1RM in untrained men [17]. The mechanism proposed for the exercise-induced increase in Hcy production is likely related to the enhanced methionine methylation and subsequent Hcy synthesis triggered by exercise. While there is currently no research on the impact of acute RE on ox-LDL concentration, recent findings have demonstrated higher circulating levels of ox-LDL in overweight and obese individuals compared to those with normal weight [18]. Furthermore, these findings have shown an increase in LDL oxidation due to the generation of free radicals [19]. Therefore, it is evident that the most effective strategy to counteract LDL oxidation and Hcy production involves incorporating an antioxidant-rich diet to reinforce antioxidant systems and prevent the production of reactive oxygen species (ROS).

Previous research has highlighted the positive impact of beta-carotene, alpha-tocopherol, and green tea catechins on LDL oxidation and Hcy production [20-23]. Green tea, in particular, has gained significant attention as a herbal antioxidant [24]. It contains polyphenol catechins such as (−)-epigallocatechin gallate (EGCG), (−)-epicatechingallate (ECG), (−)-epigallocatechin (EGC), (−)-epicatechin (EC), and epigallocatecanine (EGCG), which exhibit potent antioxidant properties and have been shown to inhibit LDL oxidation [23, 25, 26]. Intense exercise can lead to an increase in free radicals like reactive oxygen species (ROS) and reactive nitrogen species (RNS), surpassing the body's antioxidant capacity and resulting in oxidative stress that can damage cellular structures such as proteins, lipids, and DNA. Earlier studies have demonstrated that green tea extract (GTE) containing 250 mg of catechins enhances antioxidant capacity and prevents oxidative damage in healthy individuals [27]. However, there is currently no research on the effects of GTE on atherosclerosis biomarkers following RE in obese individuals. Therefore, the present study aimed to investigate the impact of GTE on Hcy and ox-LDL levels, which serve as biological markers for atherosclerosis, after RE at 75% of one repetition maximum (1RM) in obese men.

Material and Methods

Study Design and Participants

Ten obese men (BMI above 30 kg/m^2) who were apparently healthy volunteered to participate in this study (Table 1). The participants were non-smokers, free from any diseases, not taking any medications or antioxidant supplements, and had not consumed any polyphenolic-rich foods for the past four months. Additionally, none of them had engaged in regular exercise training within the previous six months. The protocol followed the guidelines set by the Human Ethics Committee of the institutional review board, and all participants provided written informed consent before participating in the study.

Table 1. Physical characteristics of the subjects (n=10) in GTE and PL conditions.

Variables	Group	Mean±SD
Age (y)	GTE	43.45±3.2
	PL	45.80±4.12
Height (m)	GTE	1.75±0.02
	PL	1.78±0.01
Weight (kg)	GTE	110.25±7.5
	PL	112.5±5.5
BMI (kg.m^{-2})	GTE	32.42±1.70
	PL	33.06±2.25

Experimental Procedure

The study employed a randomized, double-blind, placebo-controlled, crossover design, which included two 14-day supplementation periods followed by a RE protocol and a subsequent 14-day washout period [28]. One week prior to the supplementation, participants visited the human performance laboratory for familiarization, completion of the Par-Q Health History questionnaire, and measurement of their one-repetition maximum (1RM) in various exercises such as bench press, lat pull down, biceps curl, leg flexion, leg extension, and leg press. Throughout the study, participants were instructed to

maintain their regular diets and refrain from engaging in any additional physical activity. Before each testing session, participants recorded their food intake for three consecutive days (Saturday, Monday, and Wednesday) to ensure consistency in their dietary patterns during the two RE protocols, based on the information provided in their dietary record sheets.

In a randomized, double-blind, crossover design, participants ingested either green tea extract (GTE) or a placebo (PL) for 14-day periods, with each consisting of 2 capsules per day. Both the GTE (250 mg GTE gelatin capsules, Olimp Labs, Poland) and PL (250 mg Maltodextrin) capsules were identical in shape, size, and color. The participants took the GTE and PL capsules twice a day, during breakfast and dinner, with an adequate amount of water. Each GTE capsule (55% EGCG) contained 249 mg of polyphenols, including 200 mg of catechins (137.5 mg EGCG). On the 15th day of each supplementation period, participants returned to the human performance laboratory. They took one capsule of either GTE or PL in the morning and an additional capsule one hour before the RE protocol [28]. The RE protocol consisted of three sets to exhaustion for exercises such as bench press, lat pull down, biceps curl, leg flexion, leg extension, and leg press, with a weight equivalent to 75% of their one-repetition maximum (1RM) and a 2-minute rest between sets and exercises [28]. Prior to the RE protocols, all subjects performed a warm-up, which included a 3-minute run, 5-10 repetitions at 50% of their perceived maximum, and a stretching period (Figure 1).

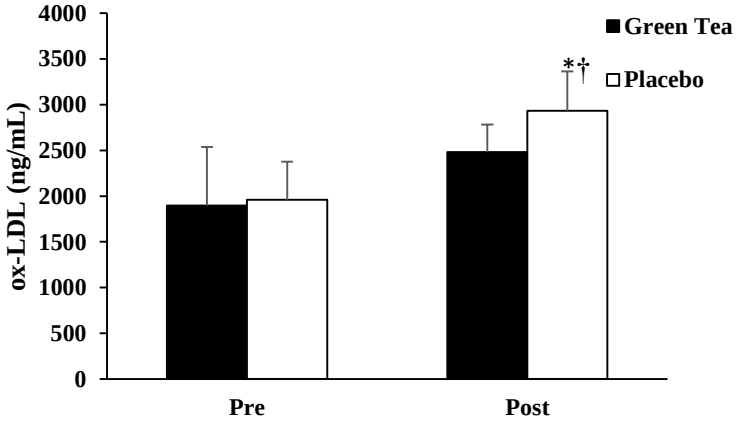

Figure 1. Serum ox-LDL concentrations in pre- and post-RE in GTE and PL condition in obses men (Mean±SD).
* Significant difrences with pre-RE (p<0.05).
† Significant difrences with GTE (p<0.05).

Biochemical Analysis

Forearm vein blood samples were collected from the participants before (pre) and immediately after (post) performing the resistance exercise (RE) to determine the serum concentrations of Hcy and ox-LDL. The serum was obtained by centrifuging the blood samples at 3000 rpm for 10 minutes at 4ºC and then stored at -80ºC for later analysis. The serum concentrations of Hcy (Cat.No. FHCY100, Axis-Shield, UK) and ox-LDL (Cat.No: CK-E10869, HANGZHOU EASTBIOPHARM CO.,LTD) were measured using commercially available ELISA kits.

Statistical Methods

The data are presented as Mean ± SD. Statistical analysis was conducted using SPSS 21 (SPSS, Chicago, IL) for Windows. The changes in serum levels of ox-LDL and Hcy were analyzed using a repeated-measures analysis of variance (ANOVA) with a 2 (treatments) × 2 (times) design. Post hoc analysis was performed using the Bonferroni test. In cases where significant interaction effects were observed ($p \leq 0.05$), independent and paired t-tests were used to assess simple main effects. The significance level was set at $p < 0.05$.

Results

The serum concentrations of ox-LDL and Hcy were analyzed using a 2-way ANOVA. The supplementation (green tea vs. placebo) was considered as the between-subjects factor, and

the time of measurement (pre and post) was considered as the within-subject factor.

The results showed a significant main effect of time (F=19.40, η^2=0.58, p=0.001) and treatment (F=5.95, η^2=0.48, P=0.029) on serum ox-LDL concentration. However, there was no significant interaction between treatment and time (F=1.28, η^2=0.08, p=0.28).

After the RE, the post-RE ox-LDL concentrations significantly increased in the placebo condition (p=0.003), but there was no significant change in the GTE condition (P=0.078). The post-RE serum ox-LDL concentration was significantly higher in the placebo condition compared to the GTE condition (p=0.029) (Figure 1).

The results regarding Hcy concentrations were presented in Figure 2. The analysis showed a significant main effect of time (F=10.02, η^2=0.41, p=0.007), indicating that there was a difference in Hcy concentrations between pre and post measurements. However, there was no significant main effect of treatment (F=2.91, η^2=0.17, p=0.11) or interaction between treatment and time (F=1.85, η^2=0.11, P=0.19; Figure 2).

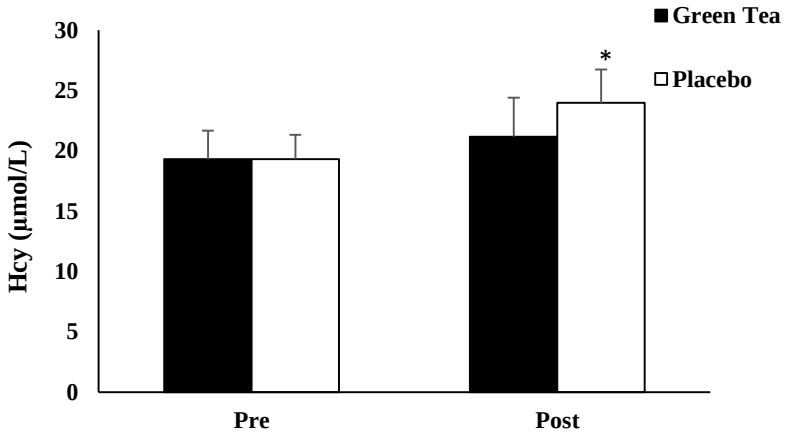

Figure 2. Serum Hcy concentrations in pre- and post-RE in GTE and PL condition in obses men (Mean±SD).
* Significant difrences with pre-RE (P<0.05).

Specifically, the serum concentrations of Hcy were significantly higher in the post-RE measurement compared to the pre-RE measurement in the placebo condition (p=0.014), but there was no significant change in the green tea extract (GTE) condition (p=0.247).

Discussion

The primary result of this study showed that consuming a short-term dose of 500 mg of GTE significantly reduced ox-LDL levels after a resistance exercise session at 75% of 1RM in untrained men with obesity. Obesity is widely acknowledged as a condition linked to elevated levels of inflammatory markers, ROS, RNS, and a decrease in antioxidant capacity. These factors are considered significant contributors to the development of various diseases, including atherosclerosis, type 2 diabetes, hypertension, and certain types of cancer [3]. Additionally, research has shown that obese individuals experience higher levels of exercise-induced oxidative stress compared to those with normal weight [29]. Therefore, it is reasonable to suggest that obese individuals should consider implementing dietary interventions, including the consumption of antioxidant-rich foods, before engaging in exercise training programs to counteract the detrimental effects associated with obesity. In this study, obese untrained men were given a daily dose of 500 mg of green tea extract (GTE) for two weeks prior to participating in a resistance exercise (RE) session at 75% of their one-repetition maximum (1RM). The results showed no significant differences in Hcy levels between the GTE and PL conditions following the short-term supplementation period. However, there was a notable trend indicating a greater percentage change in Hcy concentration in the PL condition (26.14%) compared to the GTE condition (11.53%) in response to RE. This suggests that GTE led to a

14.61% reduction in the Hcy response to RE in obese men. To the best of our knowledge, no previous studies have investigated the effect of GTE on serum Hcy levels after exercise, not only in individuals with normal weight but also in the obese population.

Hcy is widely recognized as an independent risk factor for cardiovascular diseases (CVD) [13]. A meta-analysis conducted by Boushey et al. (1995) concluded that Hcy is an independent risk factor for atherosclerosis in coronary, cerebral, and peripheral arteries. They found that every 5 μmol/L increase in total plasma Hcy level increases the risk of coronary artery disease by 60% in males and 80% in females [13]. Furthermore, a decrease of 3 μmol/L in Hcy has been reported to reduce the risk of ischemic heart disease by 16% [30]. Elevated levels of circulating Hcy pose a risk for CVD through various mechanisms. These mechanisms include inhibiting anticoagulant reactions associated with the endothelium, promoting platelet accumulation and thrombosis through oxidative stress, and activating signal transmission pathways that lead to inflammation and apoptosis [6]. These factors contribute to the increased risk of CVD associated with elevated Hcy levels.

A previous study reported that consuming green tea for one month resulted in a notable decrease in Hcy levels and a significant increase in antioxidant levels among patients with coronary artery disease [22]. However, our findings are inconsistent with this study [22]. The disparity in results could be attributed to variations in the duration of supplementation (one month vs. two weeks) and differences in the participant populations (CVD patients vs. obese individuals). It appears that the beneficial effects of green tea supplements may require a longer duration of use to be observed effectively.

Previous studies have reported an increase in Hcy levels following acute circuit resistance exercise (RE) with 40% and 35% of one-repetition maximum (1RM) in overweight and untrained men and women [16, 17]. In our present study, we observed increases of 11.53% and 26.14% in Hcy density after a resistance exercise session in obese males who consumed green tea and a placebo for 14 days, respectively. These findings indicate that resistance exercise has an impact on increasing Hcy levels, which is consistent with previous research [16, 17]. In a study conducted by Iglesias et al. (2012), an increase of 25.7% in Hcy levels was observed in 8 untrained males after cycling at 85% of their VO_2Peak. This increase is somewhat similar to the Hcy response (26.14%) observed in our study after resistance exercise under placebo conditions [31]. Other studies examining the acute effects of exercise on Hcy levels in trained participants have shown diverse results. Some studies found no effects [32-34], while others observed significant increases [11, 31, 35, 36] or decreases in circulating Hcy levels after intense exercise [37].

The increase in Hcy levels after exercise has been attributed to various mechanisms [38, 39]. One proposed mechanism suggests that the temporary decrease in renal blood flow during exercise is associated with an elevation in Hcy concentration [39]. Another potential mechanism is related to energy metabolism and substrate utilization, which can vary based on the intensity and duration of exercise [38]. Additionally, several studies have suggested a role for Hcy in energy metabolism [38, 40]. During intense exercise, such as resistance exercise (RE), there is a high demand for creatine to support energy production. This process of creatine synthesis in the liver may contribute to the formation of Hcy. It has been previously reported that approximately 75% of daily Hcy production is attributed to creatine synthesis in the liver [41].

In our current study, supplementation with GTE resulted in a 14.61% reduction in the circulating Hcy response to RE compared to a PL in obese men. This finding suggests a beneficial effect of GTE on this risk factor for cardiovascular disease. The exact mechanism by which GTE decreases Hcy levels is not fully understood. However, several mechanisms have been suggested, including the presence of folacin (folic acid) [42] and the antioxidant properties of catechin (EGCG) found in green tea [43].

Elevated levels of Hcy in the bloodstream have been linked to the oxidation of LDL and the formation of ox-LDL, which contributes to the early development of atherosclerosis lesions [44]. Previous studies have demonstrated that antioxidant supplements can inhibit LDL oxidation, reduce LDL sensitivity to oxidation, and decrease the production of ox-LDL [45, 46].

In our current study, the main finding was that obese participants who consumed 500 mg of GTE

daily for two weeks experienced a reduction in LDL oxidation. This reduction occurred in individuals who engaged in acute resistance exercise at 75% of their 1RM. While there are no specific studies on the effect of GTE on ox-LDL levels after intense exercise, previous research has shown that EGCG in green tea can inhibit LDL oxidation induced by Cu+2 ions, leading to a decrease in ox-LDL and an improvement in cardiovascular function [25] [26].

Furthermore, various studies have confirmed the role of lipoxygenase in LDL oxidation caused by endothelial cells and macrophages [47, 48]. The catechins present in green tea can inhibit lipoxygenase enzymes and act as scavengers of free radicals, functioning as chain-breaking antioxidants [49, 50]. Additionally, a study involving 12 healthy untrained men who consumed 600 ml of green tea daily for four weeks demonstrated a significant decrease in ox-LDL levels [51].

Anaerobic activities, such as RE, can trigger the production of ROS through various mechanisms, including the xanthine-xanthine oxidase pathway, neutrophilic respiratory burst, self-oxidation of catecholamines, hypoxia-ischemia, and conversion of superoxide to hydroxyl radicals [52]. The production of ROS through these pathways can lead to the oxidation of LDL. In our current study, we observed that LDL oxidation increased to a greater extent in the PL condition compared to the GTE condition during RE. This finding is consistent with previous studies that examined the effect of intense exercise on LDL sensitivity to oxidation, which also demonstrated an increase in LDL oxidation after acute exercise [53, 54]. Ox-LDL is taken up by Lectin-Like Ox-LDL Receptor 1, which is expressed on the endothelial cells of blood vessels. This uptake leads to an increase in intracellular ROS production, activating the NF- κ B pathway [55]. Ox-LDL also enhances the expression of monocyte-chemoattractant protein-1 (MCP-1) in macrophages [56] and endothelial cells [57]. The expression of MCP-1 on endothelial cells plays a crucial role in the migration of monocytes to the subendothelial space [57]. During this process, monocytes transform into macrophages, and a significant amount of LDL-cholesterol is absorbed by macrophages, leading to the formation of foam cells.

Conclusion

In summary, the short-term supplementation of GTE containing 498 mg of polyphenols, including 275 mg of EGCG, in obese men resulted in a reduction in LDL oxidation following acute RE. This reduction in LDL oxidation has the potential to delay the progression of atherosclerosis and decrease the risk of coronary disease by inhibiting LDL oxidation and foam cell formation. Additionally, GTE supplementation showed a tendency to improve circulating Hcy levels in response to acute RE, with a reduction of 2.81 μmol/L (14.61%). This reduction in Hcy level is approximately equivalent to a 10% decrease in the risk factor for cardiovascular disease [30]. Therefore, it is recommended that the obese population, before engaging in intense acute exercise, consider consuming GTE to reduce cardiovascular disease risk factors. Overall, our findings, combined with previous studies, suggest the beneficial effects of GTE on circulating ox-LDL and Hcy levels in obese individuals participating in acute RE. However, further research is needed to determine the long-term effects of GTE supplementation and higher doses on cardiovascular disease risk factors in the obese population.

Declarations

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Author Contributions

M.R.R. contributed to the conceptualization, methodology, formal analysis, investigation, and writing of the original draft. A.J. was involved in the design, research, and data collection for the project. All authors have read the manuscript and agree with its content.

Data Availability

All data used in this manuscript will be made available upon reasonable request.

Submission Statement

This manuscript is not being submitted for review or publication elsewhere while it is under review for this journal.

Ethical Approval

The protocol followed the standards set by the Human Ethics Committee of the institutional review board. All participants provided written informed consent to participate in the study.

Conflict of Interest

The author declares no conflicts of interest in relation to this work.

References

1. Padwal RS. Obesity, diabetes, and the metabolic syndrome: the global scourge. Canadian Journal of Cardiology. 2014; 30(5):467-72.
2. Zhang P, Xu X, Li X. Cardiovascular diseases: oxidative damage and antioxidant protection. Eur Rev Med Pharmacol Sci. 2014; 18(20):3091-6.
3. Huang C-J, McAllister MJ, Slusher AL, Webb HE, Mock JT, Acevedo EO. Obesity-related oxidative stress: the impact of physical activity and diet manipulation. Sports Medicine-Open. 2015; 1(1):32.
4. Tsutsui T, Tsutamoto T, Wada A, Maeda K, Mabuchi N, Hayashi M, Ohnishi M, Kinoshita M. Plasma oxidized low-density lipoprotein as a prognostic predictor in patients with chronic congestive heart failure. Journal of the American College of Cardiology. 2002; 39(6):957-62.
5. Toshima S-i, Hasegawa A, Kurabayashi M, Itabe H, Takano T, Sugano J, Shimamura K, Kimura J, Michishita I, Suzuki T: Circulating oxidized low density lipoprotein levels: a biochemical risk marker for coronary heart disease. Arteriosclerosis, Thrombosis, and Vascular Biology. 2000; 20(10):2243-7.
6. Joubert LM, Manore MM. Exercise, nutrition, and homocysteine. International journal of sport nutrition and exercise metabolism 2006; 16(4):341-61.
7. Fogelman AM, Shechter I, Seager J, Hokom M, Child JS, Edwards PA. Malondialdehyde alteration of low density lipoproteins leads to cholesteryl ester accumulation in human monocyte-macrophages. Proceedings of the National Academy of Sciences. 1980; 77(4):2214-8.
8. Stanton LW, White RT, Bryant CM, Protter AA, Endemann G. A macrophage Fc receptor for IgG is also a receptor for oxidized low density lipoprotein. Journal of Biological Chemistry. 1992; 267(31):22446-51.
9. Brustolin S, Giugliani R, Félix T. Genetics of homocysteine metabolism and associated disorders. Brazilian Journal of Medical and Biological Research 2010, 43(1):1-7.
10. Neves LB, Macedo DM, Lopes AC: Homocysteine. Jornal Brasileiro de Patologia e Medicina Laboratorial 2004, 40(5):311-20.
11. König D, Bisse E, Deibert P, Müller H-M, Wieland H, Berg A. Influence of training volume and acute physical exercise on the homocysteine levels in endurance-trained men: interactions with plasma folate and vitamin B12. Annals of nutrition and metabolism. 2003, 47(3-4):114-8.
12. Pfanzagl B, Tribl F, Koller E, Möslinger T. Homocysteine strongly enhances metal-catalyzed LDL oxidation in the presence of cystine and cysteine. Atherosclerosis. 2003; 168(1):39-48.
13. Boushey CJ, Beresford SA, Omenn GS, Motulsky AG: A quantitative assessment of plasma homocysteine as a risk factor for vascular disease: probable benefits of increasing folic acid intakes. Jama. 1995; 274(13):1049-57.
14. Deminice R, Ribeiro DF, Frajacomo FTT. The effects of acute exercise and exercise training on plasma homocysteine: a meta-analysis. PloS one. 2016; 11(3):e0151653.
15. e Silva AdS, da Mota MPG. Effects of physical activity and training programs on plasma homocysteine levels: a systematic review. Amino acids. 2014; 46(8):1795-804.
16. Bizheh N, Gharahcholo L. The response of homocysteine and insulin resistance to a single circuit resistance exercise in overweight women. Journal of Shahrekord University of Medical Sciences. 2013; 15(3):9-17.
17. Bizheh N, Jaafari M, The effect of a single bout circuit resistance exercise on homocysteine, hs-CRP and fibrinogen in sedentary middle aged men. Iranian Journal of Basic Medical Sciences. 2011; 14(6):568.
18. Kosola J, Ahotupa M, KyrÖlÄinen H, Santtila M, Vasankari T. Good aerobic or muscular fitness protects overweight men from elevated oxidized LDL. Medicine & Science in Sports & Exercise. 2012; 44(4):563-8.
19. Chisolm GM, Hazen SL, Fox PL, Cathcart MK. The oxidation of lipoproteins by monocytes-macrophages biochemical and biological mechanisms. Journal of Biological Chemistry. 1999; 274(37):25959-62.
20. Bocan TM, Mueller SB, Brown EQ, Uhlendorf PD, Mazur MJ, Newton RS. Antiatherosclerotic effects of antioxidants are lesion-specific when evaluated in hypercholesterolemic New Zealand white rabbits. Experimental and molecular pathology. 1992; 57(1):70-83.
21. Shaish A, Daugherty A, O'sullivan F, Schonfeld G, Heinecke JW: Beta-carotene inhibits atherosclerosis in hypercholesterolemic rabbits. The Journal of Clinical Investigation. 1995; 96(4):2075-82.
22. Jalali F, Hajian TK, Pouramir M, Farzadi M. The Effects of Green Tea on Serum Lipids, Antioxidants, and Coagulation Tests in Stable Coronary Artery Disease: A Prospective Interventional Study. 2008.
23. Suzuki K, Takahashi M, Li C-Y, Lin S-P, Tomari M, Shing CM, Fang S-H. The acute effects of green tea and carbohydrate coingestion on systemic inflammation and oxidative stress during sprint cycling. Applied Physiology, Nutrition, and Metabolism. 2015; 40(10):997-1003.
24. Forney GB, Morré DJ, Morré DM. Oxidative stress reduced by a green tea concentrate and capsicum combination: synergistic effects. Journal of Dietary Supplements. 2013; 10(4):318-24.
25. Miura S, Watanabe J, Sano M, Tomita T, Osawa T, Hara Y, Tomita I. Effects of various natural antioxidants on the Cu2+-mediated oxidative modification of low density lipoprotein. Biological and Pharmaceutical Bulletin 1995, 18(1):1-4.
26. Tinahones F, Rubio M, Garrido-Sanchez L, Ruiz C, Gordillo E, Cabrerizo L, Cardona F: Green tea reduces

LDL oxidability and improves vascular function. Journal of the American College of Nutrition 2008, 27(2):209-213.
27. Erba D, Riso P, Bordoni A, Foti P, Biagi PL, Testolin G. Effectiveness of moderate green tea consumption on antioxidative status and plasma lipid profile in humans. The Journal of Nutritional Biochemistry. 2005; 16(3):144-9.
28. Rahimi R, Falahi Z. Effect of green tea extract on exercise-induced oxidative stress in obese men: a randomized, double-blind, placebo-controlled, crossover study. Asian Journal of Sports Medicine. 2017;8(2).
29. Vincent HK, Morgan JW, Vincent KR: Obesity exacerbates oxidative stress levels after acute exercise. Medicine and science in sports and exercise 2004, 36(5):772-9.
30. Wald DS, Law M, Morris JK: Homocysteine and cardiovascular disease: evidence on causality from a meta-analysis. BMJ. 2002; 325(7374):1202.
31. Iglesias-Gutierrez E, Egan B, Díaz-Martínez ÁE, Penalvo JL, Gonzalez-Medina A, Martínez-Camblor P, O'Gorman DJ, Ubeda N. Transient increase in homocysteine but not hyperhomocysteinemia during acute exercise at different intensities in sedentary individuals. PloS One. 2012; 7(12):e51185.
32. De Crée C, Whiting PH, Cole H. Interactions between homocyst (e) ine and nitric oxide during acute submaximal exercise in adult males. International Journal of Sports Medicine. 2000; 21(04):256-2.
33. De Crée C, Lane NP, Whiting PH, Cole H: Interactions Between Homocyst (e) ine And Nitric Oxide During Acute Submaximal Exercise In Adult Males. Medicine & Science in Sports & Exercise. 1999; 31(5):S163.
34. Wright M, Francis K, Cornwell P. Effect of acute exercise on plasma homocysteine. The Journal of sports medicine and physical fitness. 1998; 38(3):262-5.
35. Gelecek N, Teoman N, Ozdirenc M, Pınar L, Akan P, Bediz C, Kozan O: Influences of acute and chronic aerobic exercise on the plasma homocysteine level. Annals of Nutrition and Metabolism. 2007; 51(1):53-8.
36. Herrmann M, Schorr H, Obeid R, Scharhag J, Urhausen A, Kindermann W, Herrmann W. Homocysteine increases during endurance exercise. Clinical Chemistry and Laboratory Medicine. 2003; 41(11):1518-24.
37. Gaume V, Mougin F, Figard H, Simon-Rigaud M, N'guyen U, Callier J, Kantelip J, Berthelot A: Physical training decreases total plasma homocysteine and cysteine in middle-aged subjects. Annals of nutrition and metabolism. 2005; 49(2):125-31.
38. Jeukendrup A. Modulation of carbohydrate and fat utilization by diet, exercise and environment. In. Portland Press Limited. 2003.
39. Venta R, Cruz E, ValcÁrcel G, Terrados N. Plasma vitamins, amino acids, and renal function in postexercise hyperhomocysteinemia. Medicine and science in Sports and Exercise. 2009; 41(8):1645-51.
40. Wang Z, Pini M, Yao T, Zhou Z, Sun C, Fantuzzi G, Song Z. Homocysteine suppresses lipolysis in adipocytes by activating the AMPK pathway. American Journal of Physiology-Endocrinology and Metabolism. 2011; 301(4):E703-12.
41. Selhub J. Homocysteine metabolism. Annual review of nutrition. 1999; 19(1):217-46.
42. Chen T-S, Lui C, Smith CH. Folacin content of tea. Journal of the American Dietetic Association. 1983; 82(6):627-32.
43. Yang T, Koo M. Inhibitory effect of Chinese green tea on endothelial cell-induced LDL oxidation. Atherosclerosis. 2000; 148(1):67-73.
44. Witztum JL, Steinberg D. Role of oxidized low density lipoprotein in atherogenesis. The Journal of clinical investigation. 1991; 88(6):1785-92.
45. Jialal I, Fuller CJ, Huet BA. The effect of α-tocopherol supplementation on LDL oxidation: A dose-response study. Arteriosclerosis, thrombosis, and vascular biology. 1995; 15(2):190-8.
46. Jialal L, Grundy S. Effect of combined supplementation with [alpha]-tocopherol, ascorbate and beta carotene on low-density lipoprotein oxidation. The Endocrinologist. 1994; 4(3):226.
47. Folcik V, Nivar-Aristy R, Krajewski L, Cathcart M. Lipoxygenase contributes to the oxidation of lipids in human atherosclerotic plaques. The Journal of Clinical Investigation. 1995; 96(1):504-10.
48. Bailey JM, Makheja A, Lee R, Simon T. Systemic activation of 15-lipoxygenase in heart, lung, and vascular tissues by hypercholesterolemia: relationship to lipoprotein oxidation and atherogenesis. Atherosclerosis. 1995; 113(2):247-58.
49. Ho C-T, Chen Q, Shi H, Zhang K-Q, Rosen RT. Antioxidative effect of polyphenol extract prepared from various Chinese teas. Preventive Medicine. 1992; 21(4):520-5.
50. Salah N, Miller NJ, Paganga G, Tijburg L, Bolwell GP, Riceevans C. Polyphenolic flavanols as scavengers of aqueous phase radicals and as chain-breaking antioxidants. Archives of Biochemistry and Biophysics. 1995; 322(2):339-46.
51. Sung H, Min W-K, Lee W, Chun S, Park H, Lee Y-W, Jang S, Lee D-H. The effects of green tea ingestion over four weeks on atherosclerotic markers. Annals of clinical biochemistry. 2005; 42(4):292-7.
52. Ji LL. Free radicals and antioxidants in exercise and sports. Exercise and Sport Science. 2000:299-317.
53. Sanchez-Quesada J, Homs-Serradesanferm R, Serrat-Serrat J, Serra-Grima J, Gonzalez-Sastre F, Ordonez-Llanos J. Increase of LDL susceptibility to oxidation occurring after intense, long duration aerobic exercise. Atherosclerosis. 1995; 118(2):297-305.
54. Wetzstein CJ, Shern-Brewer RA, Santanam N, Green NR, White-Welkley JE, Parthasarathy S. Does acute exercise affect the susceptibility of low density

lipoprotein to oxidation?. Free Radical Biology and Medicine. 1998; 24(4):679-82.
55. Nishimura S, Akagi M, Yoshida K, Hayakawa S, Sawamura T, Munakata H, Hamanishi C. Oxidized low-density lipoprotein (ox-LDL) binding to lectin-like ox-LDL receptor-1 (LOX-1) in cultured bovine articular chondrocytes increases production of intracellular reactive oxygen species (ROS) resulting in the activation of NF-κB. Osteoarthritis and cartilage. 2004; 12(7):568-76.
56. Wang G-P, Deng Z-D, Ni J, Qu Z-L. Oxidized low density lipoprotein and very low density lipoprotein enhance expression of monocyte chemoattractant protein-1 in rabbit peritoneal exudate macrophages. Atherosclerosis. 1997; 133(1):31-6.
57. Li D, Mehta JL: Antisense to LOX-1 inhibits oxidized LDL–mediated upregulation of monocyte chemoattractant protein-1 and monocyte adhesion to human coronary artery endothelial cells. Circulation. 2000; 101(25):2889-95.