Nutrition 32 (2016) 321–331

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Influence of green tea catechins on oxidative stress metabolites at rest and during exercise in healthy humans

Masaaki Sugita Ph.D. [a], Mahendra P. Kapoor Ph.D. [b,*], Akinobu Nishimura M.D., Ph.D. [c], Tsutomu Okubo Ph.D. [b]

[a] Faculty of Education, University of Mie, Tsu city, Mie, Japan
[b] Taiyo Kagaku Co. Ltd., Nutrition Division, Yokkaichi, Mie, Japan
[c] Graduate School of Medicine, Faculty of Medicine, University of Mie, Tsu City, Mie, Japan

ARTICLE INFO

Article history:
Received 20 March 2015
Accepted 11 September 2015

Keywords:
Green tea
Catechins
Antioxidant
Stress metabolites
Exercise

ABSTRACT

Objectives: The aim of this study was to investigate the effects of green tea catechins (GTC) on oxidative stress metabolites in healthy individuals while at rest and during exercise. The effects investigated included response to fat metabolism, blood lactate concentrations, and rating of perceived exertion.

Methods: In a paralleled, crossover, randomized controlled study, 16 trained male gymnastic students were randomly divided into two groups. The rest group (n = 8; GTC-NEX) received a single dose of 780 mg GTC with water but no exercise; the exercise group (n = 8; GTC-EX) received a similar dose of GTC but were instructed to exercise. This was followed by a crossover study with similar exercise regime as a placebo group (PL-EX) that received water only. Blood samples were collected at baseline and after 60 and 120 min of GTC intake. Oxidative stress blood biomarkers using the diacron reactive oxygen metabolite (d-ROMs) and biological antioxidant potential (BAP) tests; urinary 8-hydroxydeoxyguanosine (8-OHdG); 8-OHdG/creatinine; and blood lactate concentrations were analyzed. During the cycle ergometer exercise, volume of maximal oxygen uptake, volume of oxygen consumption, volume of carbon dioxide, and respiratory exchange ratio were measured from a sample of respiratory breath gas collected during low, moderate, and high intensity exercising, and the amount of fat burning and sugar consumption were calculated. Analysis of variance was used to determine statistical significance ($P < 0.05$) between and among the groups.

Results: Levels of postexercise oxidative stress metabolites BAP and d-ROMs were found significant ($P < 0.0001$) in the PL-EX and GTC-EX groups, and returned to pre-exercise levels after the recovery period. Levels of d-ROMs showed no significant difference from baseline upon GTC intake followed by resting and a resting recovery period in the GTC-NEX group. BAP levels were significant upon GTC intake followed by resting ($P = 0.04$), and after a resting recovery period ($P = 0.0006$) in the GTC-NEX group. Urinary 8-OHdG levels were significant ($P < 0.005$) for all groups after the recovery period. A significant difference was noticed between the ratios of resting BAP to d-ROMs and exercise-induced BAP to d-ROMs ($P = 0.022$) after 60 min of GTC intake, as well as resting 8-OHdG and exercise-induced 8-OHdG levels ($P = 0.004$) after the recovery period. Oxidative potentials were higher when exercise was performed at low to moderate intensity, accompanied by lower blood lactate concentration and higher amounts of fat oxidation.

Conclusions: The results of the present study indicate that single-dose consumption of GTC influences oxidative stress biomarkers when compared between the GTC-NEX and GTC-EX groups, which could be beneficial for oxidative metabolism at rest and during exercise, possibly through the catechol-*O*-methyltransferase mechanism that is most often cited in previous studies.

Introduction

Enhanced and prolonged exercise can affect antioxidant levels; therefore, the increased endogenous antioxidant capacity

MS and TO initiated the project. The authors have no conflicts of interest to declare.

* Corresponding author. Tel.: +81 706 479 6004; fax: +81 593 475 417.
E-mail address: mkapoor@taiyokagaku.co.jp (M. P. Kapoor).

http://dx.doi.org/10.1016/j.nut.2015.09.005
0899-9007/

of skeletal muscles can help promote fat metabolism during exercise, which is related to a glycogen-sparing effect. At rest, fat is the predominant fuel for energy demand in humans. A number of studies have focused on strategies and interventions used to enhance rates of fat metabolism at rest as well as during exercise [1–5]. Consumption of green tea (generally known as *Camelliia Sinensis L*) is gaining popularity in the Western world, although it is already very popular throughout Asia. Green tea contains several phytonutrients (i.e., polyphenols/catechins), mainly epigallocatechin-3-gallate (EGCG), which is the most pharmacologically active compound among the green tea catechins (GTCs). EGCG has high antioxidant activity [6,7]. Although catechins have been shown to modulate exercise performance in animals [8], limited studies have been performed on the effects of GTC on exercise performance in a large sports population. The potential effects of GTC on improved sports performance are being scientifically investigated. EGCG has been linked to an increase in performance and to maximizing lipid oxidation during aerobic exercise. This is a result of the mild thermogenic effect and enhanced expression of the β-2 adrenergic receptor gene involved in the oxidation of mitochondrial fat [9,10]. Thus, there is increasing interest in the potential of GTC to induce fat loss that might be a cumulative effect of relative increases in energy expenditure [11–13]. Although the weight loss effects of GTC intake may be attributed to elevated fat oxidation and total energy expenditure (or fat metabolism), the effect of GTC on fat metabolism may depend on the bioactivity of GTC as well as sensitivity of measuring fat oxidation. However, the exact mechanism involved in the GTC metabolites and catabolites in enhancing fat oxidation has not been fully elucidated. A study was conducted to examine the potential of green tea extract rich in polyphenols and caffeine (270 mg/d EGCG and 150 mg/d caffeine) to increase 24-h energy expenditure and fat oxidation. Study results demonstrated that fat oxidation rates were 20% higher after consumption of green tea extract than caffeine [14]. Other studies regarding the potential ergogenic effect of green tea extract that also contain caffeine have focused on increased oxidation of fat during exercise tasks. These studies demonstrated that caffeine might act synergistically with GTC or might possibly influence sympathetic nervous system (SNS) activities to enhance energy expenditure [15,16]. Many of these studies have shown a thermogenic effect, which can lead to an increase in calories burned by the body at rest by relieving inhibition at different control points. Recently, the metabolic response of supplementation with green tea extract (1200 mg catechins + 240 mg caffeine/d in two dosages) was studied in individuals at rest and during moderate intensity exercise (56% VO_2 max). The results showed enhanced lipolysis and fat oxidation under the resting condition only [3]. However, few studies are available regarding the effects of GTC (decaffeinated) on exercise-induced oxidative stress blood biomarkers. One study reported that acute consumption of decaffeinated green tea extract (890 ± 13 mg polyphenol: 366 ± 5 mg EGCG) in a 24-h period significantly ($P < 0.01$) increased fat oxidation in individuals during a single moderate exercise bout at 60% VO_2 max, whereas the average fat oxidation rates were 17% higher, thus improving insulin sensitivity and glucose tolerance in healthy young men [17]. Another well-designed randomized double-blind 12-wk study demonstrated that chronic consumption of decaffeinated green tea extract (n = 132; 625 mg catechins, of which 215 mg was EGCG) significantly increased fat oxidation in individuals who exercise moderately [18]. Compared with a control group that only exercised during the trial, individuals in the catechins group had significantly larger reductions in total abdominal fat area ($P = 0.013$) and subcutaneous abdominal fat area ($P = 0.019$). Results from another study concluded that daily GTC consumption (catechins, 572.8 mg; of which 100.5 mg was EGCG; low caffeine, 76.7 mg) for 10 wk of exercise training (3 d/wk), significantly enhanced fat oxidation ($P < 0.05$) during moderate-intensity exercise (60% VO_2 max), compared with the placebo group [19]. Another study suggested that chronic ingestion of GTC may result in upregulation of fat oxidation in healthy men during regular exercise [20].

Nevertheless, in some human studies, the stimulating effect of GTC supplementation on fat oxidation during exercise was not clearly observed. A double-blind, 3-wk crossover study reported little influence of GTC supplementation (159 mg catechins/d; of which 68 mg was EGCG; low caffeine 28 mg) on fat metabolism during exercise (50% VO_2 max), as indicated by plasma fatty acids, triacylglycerols, 3-β-hydroxybutyrate, respiratory exchange ratio (RER), energy expenditure, or a combination of these factors [21]. Such low efficacy was attributed to a relatively very small dosage of the GTC with low EGCG and caffeine contents compared with other studies that reported increased fat oxidation. In this connection, extensive research regarding caffeine has documented an influence on SNS activity and that caffeine may act synergistically with GTC to enhance energy expenditure. Little benefit of EGCG alone (270 mg/d; 6 d period) has been found on fat oxidation or cycling performance at 60% VO_2 max in moderately well-trained men [10]. Another study investigated that very short-term consumption of EGCG (405 mg/d for 2 d, and 135 mg taken 2 h before exercise test) significantly ($P < 0.04$) increased VO_2 max in healthy adults engaged in stationary cycling exercise [22]. This increase was attributed to the uncoupling of electron transport through adenosine triphosphate synthesis that is somewhat similar to *UCP-2* gene expression in 3 T3-L1 fat cells.

To date, the exact composition of GTC required to stimulate fat oxidation at rest and during endurance is unknown and relatively high caffeine content could possibly mask the effect of GTC on fat oxidative metabolites. Therefore, based on the available research results, we hypothesized that the ergogenic efficacy of decaffeinated GTC as a single dose would be possible in terms of enhanced oxidative fat metabolism at rest as well as during the exercise. Thus, the aim of present study was to examine this hypothesis with evidence of a visible effect on oxidative stress metabolites, and the body fat utilization compared with exercise alone in healthy humans. We performed a paralleled, crossover, controlled study with 16 healthy men who were normal weight gymnasts with a reasonable intake of polyphenols and related foods. To evaluate the possible ergogenic effects of GTC, we investigated the influence of a suitable single dose of GTC supplementation on energy metabolism at resting conditions and during varied intensity exercise regimens in participants.

Materials and methods

Participants and study design

Sixteen healthy, physically active, and sportive male university gymnastics students ages 20 to 23 y were enrolled in the present study. None of the participants used drugs, ergogenic aids, or antioxidant supplements for at least 8 to 10 wk before the study. Before the clinical trial, all participants were well informed about the purpose of the study and related experiment procedures. We excluded smokers and consumers of excessive green tea or any kind of food rich in polyphenols. The study was designed as a parallel, crossover, controlled study (Fig. 1) and protocols and procedures were approved by the ethical committee of the Mie University, Japan. The participants were asked to sign written and informed consent. Participants were randomly allocated into two groups: The rest group (GTC-NEX) received GTC supplementation with water without any exercise (n = 8, age 22.4 ± 1 y, weight 70.6 ± 10.3 kg, height 175.8 ± 4.5 cm), and the exercise group (GTC-EX) received GTC supplementation with exercise (n = 8,