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Original article

Effects of ginger (*Zingiber officinale Roscoe*) supplementation and resistance training on some blood oxidative stress markers in obese men

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Abstract

Excessive adiposity increases oxidative stress, and thus may play a critical role in the pathogenesis and development of obesity-associated comorbidities, in particular atherosclerosis, diabetes mellitus, and arterial hypertension. Improved body composition, through exercise training and diet, may therefore significantly contribute to a reduction in oxidative stress. Further, some foods high in antioxidants (e.g., ginger) provide additional defense against oxidation. This study was conducted to assess the effects of ginger (*Zingiber officinale Roscoe*) supplementation and progressive resistance training (PRT) on some nonenzymatic blood [total antioxidant capacity (TAC) and malondialdehyde (MDA)] oxidative stress markers in obese men. Thirty-two obese males (body mass index ≥30, aged 18–30 years) were randomized to one of the following four groups: a placebo (PL; $n = 8$); resistance training plus placebo (RTPL; $n = 8$); resistance training plus ginger supplementation (RTGI; $n = 8$); and ginger supplementation only (GI; $n = 8$). Participants in the RTGI and GI groups consumed 1 g ginger/day for 10 weeks. At the same time, PRT was undertaken by the RTPL and RTGI groups three times/week. Resting blood samples were collected at baseline and at 10 weeks, and analyzed for plasma nonenzymatic TAC and MDA concentration. After the 10-week intervention, we observed significant training × ginger supplementation × resistance training interaction for TAC ($p = 0.043$) and significant interactions for training × resistance training and training × ginger supplementation for MDA levels ($p < 0.05$). The results of this study show that 10 weeks of either ginger supplementation or PRT protects against oxidative stress and therefore both of these interventions can be beneficial for obese individuals; however, when combined, the effects cancel each other out.

Keywords: Ginger (*Zingiber officinale Roscoe*); Nonenzymatic antioxidant defense; Oxidative stress; Resistance training

Introduction

A number of published studies have shown that obesity is associated with increased oxidative stress and/or a low antioxidant status.[1–4] Increased oxidative stress is a major factor of obesity-related metabolic syndrome[5] and thus may play a significant role in the development of type 2 diabetes.[6]

Oxidative stress, also referred to as a reactive oxygen species (ROS)–antioxidant imbalance, occurs when the net amount of ROS exceeds the antioxidant capacity. Thus, oxidative stress can occur as a consequence of a general increase in ROS generation, a depression of the antioxidant defense system (enzymatic and nonenzymatic), or both.[7] Oxidative stress causes damage to biologic macromolecules such as nucleic acids, membrane lipids, and proteins, and hence disrupts normal physiological function.[3]

Oxidative stress associated with obesity can be reduced by dietary or exercise interventions.[5,6] For example, aerobic training may increase endogenous antioxidant production and

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thereby oxidative stress.[5,8] Similarly, resistance training has been shown to increase antioxidant enzyme activity, decrease oxidative stress in overweight older individuals,[9] and attenuate oxidative damage as signified by reduced plasma malondialdehyde (MDA) and peroxide levels in elderly individuals.[10]

The use of herbal medicine as a pharmacologic modality in improving antioxidant status has received attention from medical science researchers. Ginger (*Zingiber officinale Roscoe*) is a plant that belongs to the Zingiberaceae family. It is indigenous to Southeast Asia,[10] and for centuries has been an important ingredient in Chinese, Ayurvedic, and Unani-tibb herbal medicines for the treatment of different diseases.[11] It has been widely speculated that ginger might be beneficial to human health because it exerts antioxidant activity.[12] The main components of ginger are 6-gingerol, 6-shogaol, 8-gingerol, and 10-gingerol and these constituents have previously been shown to exhibit strong antioxidant activity *in vitro*.[13] Ginger extract has been shown to reduce oxidative stress[14,15] and increase plasma nonenzymatic antioxidant capacity in rodents.[16]

We have recently shown that ginger supplementation, alone or in combination with resistance training, can reduce chronic low-grade inflammation,[17] although the mechanism for this effect is not known. We speculate that the antioxidant properties of ginger may produce at least some of this beneficial effect. However, we are not aware of published studies that have tested the effects of a combination of ginger with and without resistance exercise training on oxidative stress in obese men.

Although ginger and resistance training are separately useful for improving antioxidant status in obese individuals, it is unclear whether they might have a synergistic effect when prescribed concurrently. Therefore, this study was conducted to assess the effects of progressive resistance training (PRT) and ginger supplementation on MDA and total antioxidant capacity (TAC) levels in obese men. We hypothesize that both ginger supplementation and PRT will improve antioxidant capacity and reduce oxidative stress, and a combination of the two interventions will provide increased benefit through a synergistic effect.

Materials and methods

Participants

Thirty-two obese males [body mass index (BMI) $\geq$30, aged 18–30 years] volunteered for participation after receiving a detailed explanation of the study. The study was approved by the Research Ethics Committee of Mahabad Azad University (Mahabad, Iran). All the participants had to meet the following criteria prior to enrollment in the study: (1) no regular participation in physical activity; (2) no current chronic health problems; (3) nonsmokers; (4) no cardiovascular, metabolic, or respiratory disease; and (5) no consumption of any dietary antioxidant supplements or drugs within the past 6 months. Informed consent was obtained from all participants prior to participation. All anthropometric measurements were performed by the same specialist person on the day the blood samples were taken. Height and weight were measured while the participants wore only underwear, and BMI [body weight (kg)/height (m^2)] was calculated. Body fat percent (BF%) was estimated from skin-fold measurements taken on the right side of the body at the triceps, abdominal, and suprailiac sites after 10 hours of fasting, and calculated using the formula of Brozek et al.[18]

Study design

The experimental approach to test our hypothesis was to design a randomized double-blind, placebo-controlled trial, where the interventions were administered over a 10-week period and participants were evaluated at baseline and at the end of the study. The 32 participating obese men were randomly assigned to one of the four following homogenous groups: ginger supplementation (GI; $n = 8$, age 23.7 $\pm$ 3.4 years); resistance training plus ginger (RTGI; $n = 8$, age 23.6 $\pm$ 4.4 years); placebo (PL; $n = 8$, age 25.4 $\pm$ 2.2 years); and resistance training plus placebo (RTPL; $n = 8$, age 23.7 $\pm$ 3.8 years). The groups were matched according to age, BF%, and BMI values. Thus, 16 obese men (GI and RTGI) orally received four capsules of ginger rhizome powder four times a day for 10 weeks [each capsule contained 250 mg of ginger root powder sold under the trade name Zintoma (Goldaroo Company, Tehran, Iran)], and 16 men (PL and RTPL) received 1 g of maltodextrin (placebo). Two groups, RTPL and RTGI, participated in a prescribed resistance training regime for 10 weeks, whereas the GI and PL groups did not participate in any kind of physical activity and exercise during the study period. All four groups were instructed not to change their physical activity routines or dietary patterns during the course of the study, except with regard to what was prescribed in the interventions. Moreover, to determine whether both groups had similar diets, all participants completed a validated food intake questionnaire and recorded a 24-hour food intake prior to and at the end of the study.

Training protocol

The RT program used in this study has been previously described.[2] In brief, RT was performed 3 days/week for 10 weeks, with 48–72 hours of recovery between each training session. The training consisted of seven exercises, including chest press, leg press, lateral pulldown, triceps pushdown, knee extension, seated row, and biceps curl. In addition, participants performed one abdominal exercise (abdominal curl). Prior to the start of each training session, a warm up for 15 minutes was performed. During the first 2 weeks of training, participants performed two to three sets of 15–20 repetitions at 40–50% of one repetition maximum (1RM = largest load that an individual can lift in a single maximal effort). From Weeks 3–6, participants performed each exercise for three sets, 12–15 repetitions at 50–75% 1RM. During the last 4 weeks, the number of repetitions was reduced to 8–12 whereas the intensity was increased (75–85% of 1RM). Each

participant's 1RM was reassessed every 3 weeks and at each session, the training load was adjusted accordingly. All training sessions were supervised by a qualified exercise physiologist.

Sampling protocol

Blood samples were collected from each participant at baseline and at 48–72 hours after the last exercise session in an overnight 12-hour fasted state. A 5-mL blood sample was collected by venipuncture of an antecubital vein; the resultant samples were allowed to clot at room temperature for 10 minutes and then centrifuged for 15 minutes at 0°C. The serum was then pipetted into polyethylene blood tubes and frozen at −80°C for subsequent analysis.

The TAC of plasma was evaluated by applying the ferric reducing antioxidant power or ferric reducing ability of plasma (FRAP) assay according to the method of Benzie and Strain.[19] The method is based on the reduction of ferric ion (Fe^{3+}) to ferrous (Fe^{2+}) ion at a low pH. This causes a formation of blue-colored ferrous–tripyridyltriazine complex, which absorbs at 593 nm. Plasma MDA concentration, as a circulating oxidative stress indicator, was assayed by measurement of thiobarbituric acid-reactive substances (TBARSs) according to the procedure of Mihara and Uchiyama.[20]

Statistical analyses

Prior to statistical comparison, all data sets were tested for normal distribution by the Kolmogorov–Smirnov test. Data were expressed as mean ± standard deviation and analyzed by three-way (for training pre vs. post, ginger, and resistance training) repeated-measures analysis of variance using the SPSS statistical software package (SPSS version 16.0 for Windows, SPSS Inc., Chicago, IL, USA). Significance was set at $p < 0.05$.

Results

There were no differences among groups at the beginning of this work for age, BMI, and BF% ($p > 0.05$). The plasma TAC and MDA levels prior to and after the exercise and supplement interventions were statistically compared and are shown in Fig. 1.

Overall, plasma TAC increased significantly from baseline during the study period ($p = 0.008$). There were no significant time × ginger or time × training interactions ($p = 0.814$ and $p = 0.742$, respectively). However, a significant third-order time × training × ginger interaction existed ($p = 0.043$) such that both training and ginger individually improved plasma TAC, but together they had no such effect.

In comparison with baseline values, the overall mean plasma MDA levels decreased significantly during the study period (main effect of time, $p < 0.001$). There were also interactions between time and RT and time and ginger supplementation ($p = 0.006$ and $p = 0.001$, respectively) for MDA but no three-way interaction of time × training × ginger ($p > 0.05$).

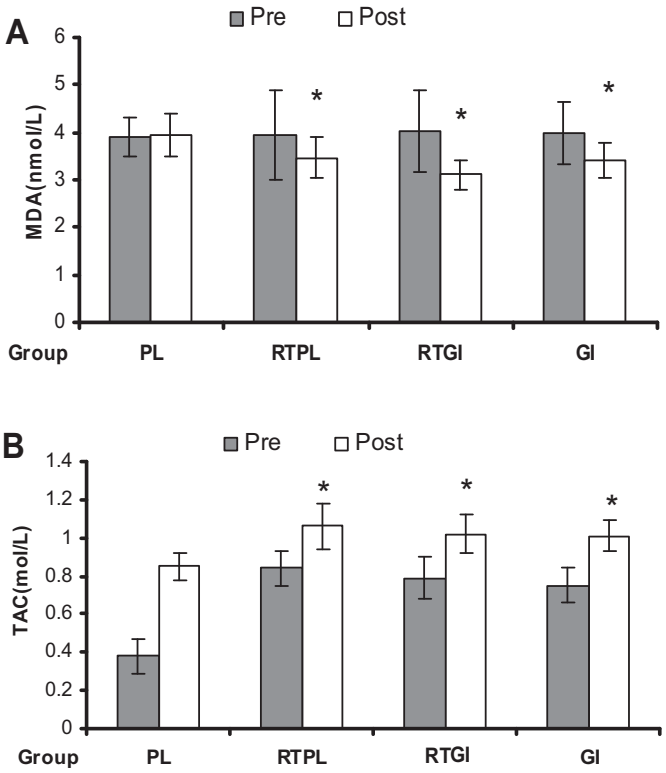

Fig. 1. (A) Oxidative stress index and (B) total antioxidant capacity prior to and after exercise and supplement interventions. Data are presented as mean ± standard deviation. * Indicates the significant difference versus baseline ($p < 0.05$). GI = ginger supplementation; MDA = malondialdehyde; PL = placebo; RTGI = resistance training plus ginger supplementation; RTPL = resistance training plus placebo; TAC = total antioxidant capacity.

In comparison with baseline values, mean BF% and fat mass decreased in the RTGI and RTPL groups ($p < 0.05$), independent of the GI and PL groups after 10 weeks. In addition, there was a mean increase in fat-free mass (FFM) in the RTGI and RTPL groups ($p < 0.05$), whereas mean FFM remained unchanged in the two other groups ($p > 0.05$). The BMI remained unchanged in all groups (Table 1).

Discussion

Increased accumulation of BF is believed to be a major factor in systemic oxidative stress,[21] and in turn may contribute to the development of type II diabetes and high blood pressure.[22] Exercise training and consumption of foods rich in antioxidants may increase physiological antioxidant defenses and thus minimizes oxidative stress.

This study investigated the effects of 10-week ginger supplementation and PRT on plasma MDA, an oxidative stress marker, and plasma nonenzymatic TAC in obese men. We found that TAC increased in the plasma of obese men after 10 weeks of ginger consumption or PRT. In addition, MDA as an indicator of oxidative stress (the main component of plasma TBARS) significantly decreased following these interventions when compared with the placebo condition.

Table 1
Body composition (prior to and after exercise) and supplement interventions.

	PL		RTPL		RTGI		GI	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Body composition								
BMI (kg/m^2)	32.2 ± 2.3	32.3 ± 2.4	32.8 ± 2.1	32.5 ± 2.0	32.5 ± 2.3	32.2 ± 2.8	31.2 ± 0.6	30.7 ± 0.7
Body fat (%)	26.0 ± 2.9	25.9 ± 2.8	26.6 ± 3.5	23.5 ± 3.3*	27.7 ± 3.6	22.7 ± 2.8*	25.6 ± 2.20	25.2 ± 3.1
FFM (kg)	74.4 ± 8.7	74.8 ± 9.3	74.5 ± 8.4	76.2 ± 6.6*	71.4 ± 8.7	74.8 ± 9.3*	67.4 ± 3.6	68.3 ± 3.3
FM (kg)	26.2 ± 2.3	25.2 ± 2.2	27.3 ± 1.6	25.1 ± 2.6*	27.5 ± 2.9	23.4 ± 2.8*	25.8 ± 2.1	24.6 ± 2.3

Data are presented as mean ± SEM.
* Indicates the significant difference versus baseline.
BMI = body mass index; FM = fat mass; FFM = fat-free mass; GI = ginger supplementation; PL = placebo; RTGI = resistance training plus ginger supplementation; RTPL = resistance training plus placebo.

There is some discrepancy in the published data regarding the status of oxidative stress following resistance training with some studies showing benefits[23] and others showing no effect.[24,25] One result of this study, that is a significant decrease in MDA, supports the results of Cakir-Atabek et al[26] who reported that whole-body resistance training performed regularly for 6 weeks decreased MDA concentration and increased glutathione (GSH) level in healthy young men, and therefore the chronic resistance training has protective effects against oxidative stress similar to aerobics.

A potential mechanism for the resistance training-induced reduction of oxidant stress could include contraction-induced antioxidant enzyme upregulation.[9] Moreover, according to the observations of Kojda and Hambrecht,[27] the antioxidant effects of exercise may not only be mediated by increased expression of antioxidant enzymes but may also include a reduced expression of pro-oxidant enzymes. By contrast, the results of this study differ from those of Rall et al[25] who reported that 12 weeks of resistance training produced no significant changes in oxidative stress as measured by concentration of urinary 8-hydroxy-2′-deoxyguanosine (8-OHdG). This discrepancy between the present result and Rall et al's[25] finding may be due to the differences in measured variables (8-OHdG vs. MDA) as well as due to physical fitness and ages of the participating cohorts. Similarly, McAnulty et al[24] indicated that exhaustive resistance exercise and carbohydrate ingestion had no effect on oxidative stress or plasma antioxidant potential measured by FRAP in trained individuals. The dissonance in observations between studies may have resulted from the differing of exercise training protocols (intensity, duration, and frequency of various exercises).

Currently there is a strong interest in the study of natural compounds with free radical scavenging capacity.[14] Several studies have shown that ginger is endowed with strong *in vitro* and *in vivo* antioxidant properties,[11] and through augmentation of plasma antioxidant capacity, decreases plasma free radical damage.[16] A result of this study was that ginger supplementation significantly decreased a plasma oxidative stress marker (MDA) and increased TAC (as indicated by FRAP) in obese men. These findings are consistent with the results of previously published work by others.[14,16,28,29] It is suggested that some factors such as reduction of lipids in the liver and plasma by ginger powder may play a role in decreasing MDA and TBARS levels.[16,29] Accordingly, Mallikarjuna et al[15] revealed that dietary ginger for 4 weeks in rats exerted an antioxidant effect by activating antioxidant enzyme status and reducing MDA in liver tissue.

One of the important questions this study aimed to address was whether the combination of RTGI supplementation had a synergistic effect on oxidative stress markers. Because exercise-induced endogenous antioxidant production is separate from that found in foods, we hypothesized that the combination of resistance training and ginger would produce a better additive effect than either alone or when training is performed separately with ginger administration. Recent research on plant-based food with high polyphenol concentrations (blueberries) has shown exercise to interact with the food to induce increases in the antioxidant potential of the blood,[30] whereas the blueberries and exercise alone did not. Interestingly, our data reveal that when administered together ginger (GI) and PRT had no effect. That is, administration of ginger cancelled out the antioxidant effect of training and vice versa. Accordingly, oxidative damage, as indicated by MDA, was reduced only when training or resistance training was performed separately, and not when performed together with ginger administration.

With the data collected, we are unable to explain this interesting finding. However, we can speculate that some sort of negative feedback mechanism exists whereby endogenous antioxidant production is inhibited when exogenous (dietary) antioxidants are introduced. Certainly, it is known that ROS provide a stimulus that produces adaptive effects in muscle,[31] and presumably other physiological systems engaged during exercise.[32] Whether or not this also occurs for endogenous antioxidant generating systems is not known.

In conclusion, the results of this study indicated that PRT for 10 weeks can improve antioxidant defending capacity and decrease oxidative stress marker in obese men. Separately, ginger supplementation has a similar effect. Therefore, it can be said that either resistance training or ginger supplementation can be an effective therapeutic intervention to reduce oxidative stress in obese individuals. However, caution should be applied to ginger supplementation during exercise training as a nutritional therapeutic to reduce oxidative stress until further relevant research is performed.

Conflicts of interest

The authors declare that they have no conflicts of interest concerning this article.

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