Original Research

*Lycium barbarum* Increases Caloric Expenditure and Decreases Waist Circumference in Healthy Overweight Men and Women: Pilot Study

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Key words: *Lycium barbarum*, goji, waist circumference, energy expenditure, resting metabolic rate, humans

**Background:** *Lycium barbarum* (*L. barbarum*), a traditional Asian medicinal therapy for diabetes and other conditions, has been shown to increase metabolic rate and to reduce body-weight gains in rodent models, as well as to produce clinical improvements in general feelings of well-being including energy level.

**Objective:** To investigate the impact of *L. barbarum* consumption on (1) caloric expenditure and (2) changes in morphometric parameters (waist circumference) in healthy human adults.

**Method:** Two separate randomized, double-blind, placebo-controlled, small clinical studies were conducted using a standardized *L. barbarum* fruit juice, GoChi, and assessing its effects on (1) resting metabolic rate (RMR) and postprandial energy expenditure (PPEE) as measured by indirect calorimetry after single-bolus intake of 3 doses of *L. barbarum* (30, 60, and 120 ml) and placebo; and (2) waist circumference and other morphometric changes in a 14-day intervention trial (120-ml daily intake) in the subjects (age = 34 years, body mass index = 29 kg/m²).

**Results:** (1) A single bolus of *L. barbarum* intake increased PPEE 1 through 4 hours postintake over the baseline level in a dose-dependent manner and was significantly higher than the placebo group by 10% at 1 hour postintake of 120 ml (*p*, 0.05). (2) In a 14-day intervention trial, *L. barbarum* was found to significantly decrease waist circumference by 5.5 ± 0.8 cm (n = 15) compared with the preintervention measurements and placebo group at postintervention day 15 (*p*, 0.01). By contrast, the changes in the placebo group (n = 14) from preinterventions was 0.9 ± 0.8 cm, which was not statistically significant.

**Conclusions:** These results show that *L. barbarum* consumption increases metabolic rate and reduces the waist circumference, relative to placebo treated control subjects.

**INTRODUCTION**

*Lycium barbarum* (*L. barbarum*) is a Solanaceous defoliated shrubbery, and the fruit (goji) has been a commonly prescribed traditional medicine in Asian countries for more than 2500 years. Modern studies indicate that *L. barbarum* and its main active constituents, *L. barbarum* polysaccharides (LBP), possess a range of biological effects, such as significantly increasing metabolic rate and body-weight reduction in mice and rats [1,2]. Other observed effects include significant clinical improvements in general well-being, including energy levels, sleep quality, glucose control in diabetics, glaucoma, antioxidant properties, antiaging, neuro-protection, antifatigue/endurance, immunomodulation, antimtor activity, and cytoprotection [3–10].

Obesity is a major health problem worldwide and is widely recognized as being associated with increased morbidity and mortality [11,12]. Abdominal obesity is strongly associated with increased cardiometabolic risk, cardiovascular events, and mortality [12–14]. One criterion for the diagnosis of metabolic
syndrome includes measurement of abdominal obesity/waist circumference because visceral adipose tissue is a key component of the syndrome [14–16].

Based on the known features of *L. barbarum* listed here, we have conducted two separate human clinical studies using a randomized, placebo-controlled procedure to explore the acute effects of *L. barbarum* on (1) resting metabolic rate (RMR) and postprandial energy expenditure (PPEE) measured by indirect calorimeter, and (2) central adiposity, as measured by waist circumference in healthy human subjects. Given that this fruit juice is the only available material standardized with regard to its active component, LBP, we have used this preparation for the present studies.

**MATERIALS AND METHODS**

*L. barbarum* and Placebo Preparation

FreeLife International Inc, Phoenix, AZ, supplied a commercially available, LBP-standardized *L. barbarum* fruit juice (GoChi; lot no. ASA07120 and ASA07351) produced from fresh, ripe *L. barbarum* fruit. The yield of juice as a percentage weight of the starting fresh plant material is about 35%. Juice was processed in an aseptic manner on an industrial scale and kept refrigerated at 2°C to 8°C. Description and standardization procedures of the test material were previously described [6]. In brief, *L. barbarum* fruit juice is standardized to contain an amount of LBP equivalent to that found in at least 150 g of fresh fruit per daily intake (120 ml), the amount customarily consumed in traditional Chinese medicine [17]. The caloric level of 120 ml of the *L. barbarum* preparation used was 64 kcal.

Placebo control material (lot no. A198) was supplied by FreeLife International and matched the color, flavor, and taste of *L. barbarum* fruit juice in a formulation of sucralose (10 mg), artificial fruit flavor (30 mg), citric acid (60 mg), and caramel color (12 mg) in 30 ml of purified water. It was packaged in the same type of container; however, it provided no LBP.

Study Population

Participants were healthy men and women, aged 18 years and older, and recruited separately for each study. In all clinical studies, the same inclusion/exclusion criteria were used but there were separate protocols for each study. Subjects were excluded from the study if they exhibited any evidence of heart, liver, lung, or kidney disease; had known allergies to *L. barbarum* or other fruit juices; were pregnant or breast-feeding; were under anticoagulant therapy such as Coumadin (warfarin); or had any acute or chronic medical or psychiatric condition. All subjects were fully informed of the purpose of the study and signed the Human Subjects Informed Consent forms approved by the internal review board organized under the Helsinki Declaration. Regarding subjects’ backgrounds, groups did not differ in prestudy diet on the parameters of the dietary intake, average *L. barbarum* consumption history, and consumption patterns for other beverages, such as sweetened beverages (soda), coffee, tea, and alcoholic beverages, or smoking history.

**Research Protocol**

Two separate clinical studies were conducted in a randomized, double-blind, placebo-controlled manner. Following enrollment in the trial, all participants completed at least 2 weeks of a washout period during which they were to discontinue their use of any *L. barbarum* or *L. barbarum*-containing foods, any dietary supplements, energy drinks, caffeinated beverages, or green tea. These restrictions were continued throughout the study based upon self-declaration in the daily dietary diary and verbal confirmation.

1. **RMR and PPEE Measurement.** Energy expenditure/caloric metabolism activity indicated by RMR and PPEE was measured by breath oxygen volume (VO₂; ml/min) using a handheld indirect calorimeter (MedGem test kit, Health Tech Inc, Golden, CO) [18,19]. Testing conditions were standardized across all subjects and followed previously established recommendations [19]. RMR and PPEE were measured for 10–15 minutes after at least 15 minutes of rest. A total of 8 subjects (21–51 years, age = 34.5 ± 7 years, body mass index [BMI] = 28.2 ± 2 kg/m²) were enrolled in and completed a randomized, double-blind, placebo-controlled, multiple-period crossover study. All test subjects randomly consumed 1 test-sample preparation on a test day. They repeated the same sample in a duplicate measurement on a different day. Test days were at least 1 week after the previous sample intake. On a test day, a basal metabolic rate was measured after at least a 12-hour overnight fast. Subjects then consumed a nutritional beverage (Boost Plus, Nestle Healthcare Nutrition Inc, Minneapolis, MN) with a known amount of calories (360 kcal) as breakfast and to stabilize the RMR throughout the 4-hour testing period [20]. In addition to this nutritional beverage, a single bolus containing 120 ml of 1 of 3 different doses of *L. barbarum* (30, 60, and 120 ml) or placebo control samples was given to the subjects. Total consumption volume of the test samples was 120 ml each time, and 90 or 30 ml of placebo solution was added to the 30- or 60-ml *L. barbarum* sample solution, respectively, and mixed well immediately before consumption. RMR was measured immediately before (baseline), 1, 2, and 4 hours after sample intake [21]. The research procedure is shown in Fig. 1.

2. **Waist Circumference and Morphometric Changes.** A randomized, placebo-controlled, double-blind clinical study was performed over a 14-day intervention period to evaluate the effect of *L. barbarum*, relative to placebo (120 ml/d), on waist circumference and other morphometric parameters. Subjects were randomly assigned to either the *L. barbarum* treatment group or placebo control. Physical morphometric
measurements were taken at the pre-, middle-, and post-intervention periods following an overnight 12-hour fast and included body weight, BMI (Seca 703, Hamburg, Germany), waist circumference at the level of umbilicus [22,23], and total body fat (Tanita BF-679W, Tokyo, Japan). All participants were monitored daily to ensure full compliance with the protocol, including sample consumption and restriction of dietary intake. Compliance was confirmed by the daily consumption of the samples in front of the research coordinator and also checked by returned empty sample bottles every day on weekdays and the Monday after the weekend. Individuals administering the physical exams were blinded as to the treatment conditions, and the treatment codes were not broken until the study was completed. *L. barbarum* or placebo sample consumption was combined with a diet restriction and exercise program in overweight/obese subjects with a BMI $\geq 25$ kg/m$^2$ (25.6–45.3 kg/m$^2$; average BMI, 29.3 $\pm$ 1.1 kg/m$^2$). Based upon our previous studies [6–9], a sample size of 35 subjects was deemed to be sufficient to detect effectiveness of *L. barbarum* with 95% confidence and 80% power. A total of 33 healthy adults (19–60 years; average age, 33.6 $\pm$ 1.9 years) consumed 90 ml of *L. barbarum* or placebo each morning with a meal and 30 ml at bedtime for a period of 14 days. Daily 15-minute walks (after lunch during weekdays) were implemented for all subjects. Subjects also wore study-provided pedometers and daily steps were recorded in a log. Caloric intake per day was restricted to approximately 1200 kcal during the 14-day intervention period by means of daily dietary diaries maintained by the subjects, 67% of whom were women. Four dropped out (2 in each group) due to personal issues not related to the sample or study.

### Statistical Analysis

Dietary intake data were analyzed with the nonparametric Mann-Whitney *U* test (placebo vs *L. barbarum*). All parametric data (body weight, height, BMI, waist circumference, body fat lean mass, VO$_2$, and RMR) were analyzed by an analysis of variance for independent and dependent groups. Descriptive statistics were calculated for placebo and *L. barbarum* for all dependent measures and summarized as means and standard errors. The data were processed using Statistica version 8 (StatSoft Inc, Tulsa, OK). Differences were considered significant at $p < 0.05$.

### RESULTS

#### Resting Metabolic Rate and Postprandial Energy Expenditure

The average baseline level of VO$_2$ in all subjects was 253.58 $\pm$ 13.13 ml/min, which was equivalent to 1761.04 $\pm$ 55.04 kcal/day. The placebo and all single boluses of various dosages of *L. barbarum* intake with nutritional beverage (360 kcal) increased RMR calculated from VO$_2$ measurement over the baseline level. At 1 hour postintake, 120 ml of *L. barbarum* intake increased 58.26 $\pm$ 5.72 ml/min of VO$_2$ over the baseline level and was significantly higher than the placebo group (24.58 $\pm$ 4.04 ml/min) ($p < 0.05$) (Fig. 2A). At 4 hours postintake, placebo control and all doses of *L. barbarum* except 120 ml intake returned to the baseline level. Conversely, VO$_2$ level after 120 ml of *L. barbarum* intake was maintained at a significantly higher level than other doses of *L. barbarum* or placebo control group ($p < 0.05$) (Fig. 2A).

The area under the curve (AUC) of VO$_2$ during 0 to 4 hours postintake of placebo control sample was 10.42 $\pm$ 4.09 L in 4 hours. The AUC of VO$_2$ after 120 ml of *L. barbarum* intake was significantly increased by 32.19 $\pm$ 3.01 L in 4 hours, which was more than twice that of the placebo level ($p < 0.05$) (Fig. 2B). This stimulus effect of *L. barbarum* on metabolic rate/energy expenditure occurred in a dose-dependent manner (Fig. 2A,B).

#### Waist Circumference

In the 14-day intervention study, daily intake of *L. barbarum* combined with exercise and dietary restriction was found to decrease waist circumference significantly in both midintervention and postintervention ($p < 0.01$) (Fig. 3). The reduction in waist circumference in the *L. barbarum* group ($n = 14$) at postintervention on day 15 was $5.54 \pm 0.65$ cm compared with that at preintervention (Fig. 3). In the placebo...
The change in waist circumference on day 15 from the preintervention was only 0.88 ± 0.83 cm, and no significant difference was found from preintervention. Other morphometric parameters, such as body weight, BMI, and total body fat did not show any statistically significant differences from the preintervention measurements in either group. Average change in body weight on day 15 in the _L. barbarum_ group from the preintervention was −0.40 ± 0.37 kg and that in the placebo group was −0.10 ± 0.17 kg (other data not shown). Thus, _L. barbarum_, in combination with modest exercise and diet restriction, has a significant effect on waist circumference.

**DISCUSSION**

The preliminary results shown in the present studies suggest that _L. barbarum_ may have provoked an increase in energy expenditure. In addition, it may lead to a reduction in central adiposity, as indicated by the reduction in waist circumference when combined with moderate dietary caloric intake restriction and mild exercise. The active compound of _L. barbarum_, LBP, is reported to enhance food conversion rate in murines and to reduce their body weight after 10–21 days of consumption [1,2]. These results suggest that _L. barbarum_ can modulate metabolism _in vivo_ and may correspond with the present study’s result regarding the effects of _L. barbarum_ on RMR/PEEE and waist circumference. These metabolic effects may also be related to the changes in adrenocortical hormone levels that contribute to energy regulation and obesity control. Our preliminary randomized, double-blind, placebo-controlled human pilot trial with 5 male subjects has shown that a single-bolus intake of _L. barbarum_ (120 ml) significantly reduced fasting salivary levels of cortisol and dehydroepiandrosterone at 7 am by 46% and 27%, respectively, compared with the placebo control group (p < 0.05). Because cortisol has been reported to increase obesity and metabolic syndrome [24],

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**Fig. 2.** Dose-response relationship of _Lycium barbarum_ on the (A) kinetic changes and (B) area under the curve (AUC) of the breath oxygen level (VO₂) analyzed by the indirect calorimeter during the 4 hours after consumption. Each value indicates mean ± standard error of measurement (in centimeters). * indicates significant increase from control level (p < 0.05).

**Fig. 3.** Changes of the waist circumference in human subjects during and after the 14-day intervention period. Each value indicates mean ± standard error of measurement (in centimeters). ** indicates significant difference from the preintervention level and the placebo group (p < 0.01).
L. barbarum (Goji) Stimulates Metabolic Rate

reduction of cortisol by L. barbarum may be related to the increased metabolic rate and decreased waist circumference. Further studies are necessary to confirm the effect on cortisol and related hormone levels, as well as to clarify an interaction with other intrinsic factors such as thyroid hormone levels, which also play important roles in a metabolic system.

The obesity epidemic is a major public health problem worldwide. Adult obesity is associated with increased morbidity and mortality [11–16]. Metabolic rate/energy expenditure was acutely and significantly increased by L. barbarum intake compared with the placebo control, and this effect may be dose-associated with the level of L. barbarum. The in vivo enhancement of the metabolic rate by L. barbarum intake may contribute to changes in waist circumference and waist-related parameters observed in the present studies. The lack of change in body weight may reflect (1) insufficient duration of exposure to L. barbarum and its bioactive compounds because the present studies were short-term trials, and (2) actions of L. barbarum may be specific to the central adiposity, independent from weight loss, as shown in a similar case with capsinoid treatment [25]. Capsinoid has been reported to significantly reduce abdominal fat without a significant body-weight reduction. Although it has been reported that oral administration of LBP reduced serum total cholesterol, low density lipoprotein, and triglyceride concentrations and increased high density lipoprotein levels in rabbits and mice [26–28], detailed analysis of the effect of L. barbarum on the fatty acid metabolism in vivo was not performed in the present studies. Therefore, detailed central adiposity analysis by dual-emission x-ray absorptiometry and lipid metabolism profile tests are required.

Although the present preliminary studies are the first clinical report to show various unique metabolic effects of L. barbarum, there are limitations in these studies because (1) each study had a small number of the subjects, and (2) the studies were short in duration, a 14-day intervention or a single-bout intake. Therefore, a larger and more long-term study is required to clarify further the effects of L. barbarum on body weight, metabolic syndrome, and glucose and fat metabolism in humans in order to confirm the efficacy and to identify the mechanisms of actions of L. barbarum.

CONCLUSION

These are the first randomized clinical trials to evaluate the role of L. barbarum in the metabolic parameters in humans. Our results suggest that L. barbarum may stimulate metabolic rate, and these effects may be related to the changes in waist circumference produced by daily consumption of L. barbarum in the form of fruit juice (GoChi) for 14 days. Further studies will determine the effects of long-term consumption of L. barbarum on body weight as well as on the development and progression of diabetes and metabolic syndrome.

ACKNOWLEDGMENTS

Authors thank Marie-Pierre St-Onge, PhD, at Columbia University, Richard Rivlin, MD, at Cornell University, and Cynthia Thomson, PhD, at University of Arizona, for their generous advice to the research and reviewing this manuscript. All sources of financial support came from FreeLife International.

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Received July 22, 2010; revision accepted August 25, 2011.