Study #6 Sedentary Men and Activity Endurance Clinical Study

Purpose

Consuming Celsius improves physiological response to exercise in previously sedentary men. A placebo controlled efficacy and safety study.

Results

Sedentary men drinking Celsius prior to moderate exercise yielded significant improvements in body composition. Participants' results included: decreased body fat, increased lean muscle, and cardio respiratory improvements compared to exercise alone.

Participants'results included:
78% greater fat loss
79% greater endurance performance
5.5 lbs fat loss

University of Oklahoma 2009

LOW-CALORIE ENERGY DRINK IMPROVES PHYSIOLOGICAL RESPONSE TO EXERCISE IN PREVIOUSLY SEDENTARY MEN: A PLACEBO-CONTROLLED EFFICACY AND SAFETY STUDY

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ABSTRACT

Lockwood, CM, Moon, JR, Smith, AE, Tobkin, SE, Kendall, KL, Graef, JL, Cramer, JT, and Stout, JR. Low-calorie energy drink improves physiological response to exercise in previously sendentary men: a placebo-controlled efficacy and safety study. *J Strength Cond Res* 23(x): 000–000, 2009—Energy drink use has grown despite limited research to support efficacy or safety and amid concerns when combined with exercise. The purpose of this study was to assess the effects of 10 weeks of once-daily energy drink consumption or energy drink consumption with exercise on measures of body composition, cardiorespiratory fitness, strength, mood, and safety in previously sedentary males. Thirty-eight males were randomly assigned to energy drink + exercise (EX-A), energy drink (NEX-A), placebo + exercise (EX-B), or placebo (NEX-B). All participants consumed 1 drink per day for 10 weeks; EX-A and EX-B participated in 10 weeks of resistance and endurance exercise. Testing was performed before (PRE) and after (POST) the 10-week intervention. No significant ($p > 0.05$) changes were observed for body composition, fitness, or strength in NEX-A; however, significantly greater decreases in fat mass and percentage body fat and increases in VO$_2$peak were observed in EX-A versus EX-B. Ventilatory threshold (VT), minute ventilation, VO$_2$ at VT, and power output at VT improved significantly PRE to POST in EX-A but not in EX-B or nonexercising groups. Clinical markers for hepatic, renal, cardiovascular, and immune function, as determined by PRE and POST blood work revealed no adverse effects in response to the energy drink. Mood was not affected by energy drink use. Absent energy restriction or other dietary controls, chronic ingestion of a once-daily low-calorie energy drink appears ineffective at improving body composition, cardio-respiratory fitness, or strength in sedentary males. However, when combined with exercise, preworkout energy drink consumption may significantly improve some physiological adaptations to combined aerobic and resistance training.

KEY WORDS caffeine, thermogenic, body composition, taurine, EGCG, green tea

INTRODUCTION

Energy drink sales for 2007 reached an estimated $6.6 billion in the United States alone, up approximately 440% from 2002 and expected to surpass $9 billion by the year 2011, with teens and young adults making up the largest consumer category (1). However, sparse data exist to support the efficacy and safety of these products when consumed chronically by active or sedentary populations, despite many of these products containing ≥200 mg of caffeine per serving (25). Instead, although some acute ingestion data have been published (2), direct and implied marketing claims of improved performance, mental acuity, and energy, improved mood and fat loss remain largely unsubstantiated for the majority of commercially available energy drinks. Safety of chronic use of commercially available energy drinks also has never been tested, to the best of our knowledge. It is appropriate that clinical concerns have been raised regarding safety, including ingestion of such products prior to or during exercise (7,8). Clauson et al. (7), for example, expressed concerns of cardiovascular complications arising from preexercise energy drink consumption.

Previous research out of our labs (9) has reported that acute oral ingestion of a commercially available, low-calorie energy drink (Celsius, Celsius, Inc, Delray Beach, Florida, USA) significantly increased resting energy expenditure (REE) and serum free fatty acid (FFA) appearance in healthy college-aged adults. Compared to placebo, the energy drink significantly increased REE (kcal/day) by approximately 10% at 120 minutes postingestion and was sustained at 180 minutes. At 30, 60, 120, and 180 minutes postingestion,

circulating FFA concentrations also were significantly elevated compared to placebo. It was concluded that the energy drink may be an effective stimulus to promote weight loss and changes in body composition, independent of modifications in diet or exercise (9). Roberts et al. (25) later examined the efficacy and safety of chronic ingestion of the same energy drink versus placebo over a 28-day period and also found a significant increase in FFA concentration in response to the energy drink. Of note, the increase in FFA appearance was similar at Day 1 and 29 of energy drink consumption; Roberts et al. concluded that prolonged consumption of the energy drink up-regulated lipolysis. Furthermore, PRE- and POST-intervention blood and serum assays revealed no significant differences between groups for all hemodynamic parameters or serum clinical chemistry/CBC markers tested.

Thus, the purpose of our investigation was to assess the effects of 10 weeks of once-daily consumption of Celsius, either alone or in combination with 5 days per week aerobic and resistance exercise, on body composition, cardiorespiratory fitness and health, upper- and lower-body strength, safety, and mood in previously sedentary but otherwise healthy adult males adhering to an ad libitum diet.

METHODS

Experimental Approach to the Problem

This study involved a minimal nutritional intervention, placebo-controlled, blinded, randomized design to simulate "real world" use of a commercially available, low-calorie energy and thermogenic beverage (Celsius, Celsius, Inc.), consumed once per day for 10 weeks, either alone or in combination with 5 days per week combined aerobic and resistance exercise. Subjects were randomly assigned into 1 of 4 groups: energy drink + exercise (EX-A), energy drink only (NEX-A), placebo + exercise (EX-B), or placebo only (NEX-B). Body composition testing and donation of blood occurred on day 1 of week 1 (PRE; or before) and week 12 (POST; or

after), after a minimum of 48 hours of abstinence from strenuous physical activity and a 12-hour fast. Cardiorespiratory and strength testing were conducted not less than 24 hours subsequent to PRE and POST blood donation. A minimum of 15 minutes of rest between completion of cardiorespiratory testing and initiation of upper-body strength testing was allowed for all subjects.

Subjects

Forty sedentary (<30 minutes of physical activity per week) men, 18 to 45 years of age, volunteered to participate in this study. Each participant was assessed by routine medical screening for inclusion. Participants were excluded if they reported or exhibited the following: (a) a history of medical or surgical events that may significantly affect the study outcome, including cardiovascular disease, metabolic, renal, hepatic, or musculoskeletal disorders; (b) use of any medicine that may significantly affect the study outcome; (c) use of nutritional supplements, other than a multivitamin/mineral, in the 4 weeks prior to the start of the study; or (d) participation in another clinical trial or ingestion of another investigational product within 30 days prior to screening. Data from 1 subject within the exercise + placebo group was removed from analysis because of noncompliance to the exercise intervention. Two subjects within the energy drink–only group were lost from the study: 1 subject failed to consume the drink while on vacation, and the other subject moved away. Therefore, of the 40 volunteers, 38 subjects completed the study and data from 37 subjects were used for analyses (see Table 1 for "Descriptive Statistics at Baseline"). This study was approved by the University of Oklahoma Institutional Review Board for Human Subjects, and written informed consent was obtained from each participant prior to testing.

Procedures

Energy Drink Intervention. All participants were instructed to consume 1 drink per day, for a total of 70 consecutive days (10 weeks). Participants in EX-A and EX-B reported to the

TABLE 1. Descriptive statistics at baseline ($\bar{x} \pm$ SEM).

GROUP	n	Age (years)	Height (cm)	Body mass (kg)	%Fat (%)	Energy (kcal/day)*	Caffeine (mg/day)*
EX-A	10	24.80 ± 1.69	176.55 ± 1.68	90.51 ± 4.18	26.62 ± 1.93	2254.05 ± 230.58	81.76 ± 26.49
NEX-A	8	23.13 ± 2.97	175.89 ± 0.74	84.89 ± 3.80	26.49 ± 1.66	2161.50 ± 188.07	36.66 ± 21.45
EX-B	9	26.56 ± 1.64	175.94 ± 2.50	93.86 ± 5.09	25.12 ± 2.98	2333.69 ± 272.07	55.81 ± 13.72
NEX-B	10	23.20 ± 2.11	176.27 ± 2.11	82.13 ± 5.75	25.84 ± 1.76	2367.05 ± 192.59	58.87 ± 12.91
	37	24.43 ± 1.03	176.18 ± 0.93	87.84 ± 2.45	26.01 ± 1.03	2287.35 ± 109.63	60.14 ± 9.75
	p-value	0.633	0.994	0.322	0.959	0.931	0.483

EX-A = exercise + Celsius; NEX-A = Celsius only; EX-B = exercise + placebo; NEX-B = placebo only.

No significant differences were observed between groups for age, height, body mass, %FAT, or total energy and caffeine intake at baseline (*p* > 0.05).

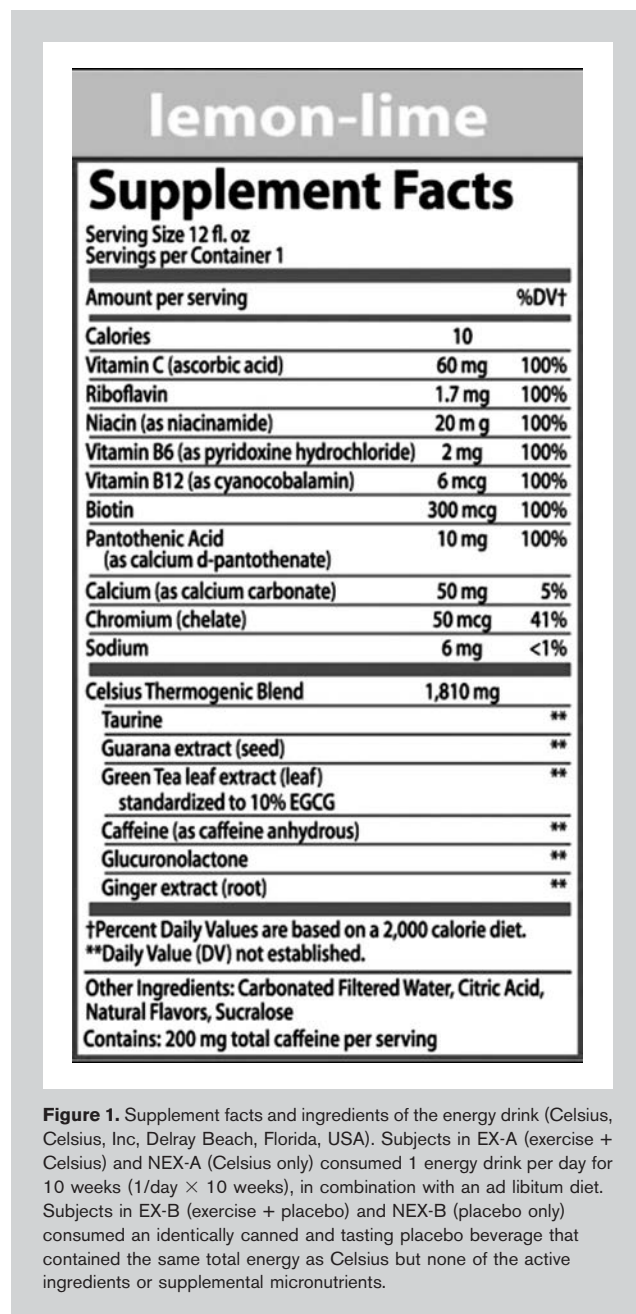*n = 36 (EX-A = 10; NEX-A = 7; EX-B = 9; NEX-B = 10).

training facility and consumed 1 drink prior to exercise, initiating exercise 15 minutes after consumption. On nonexercise days, and also for subjects in the NEX-A and NEX-B groups, time of day for consuming the beverage was left to the subject's discretion. Figure 1 provides the supplement facts panel for the beverage consumed by subjects in EX-A and NEX-A. Subjects in EX-B and NEX-B consumed an identically canned and labeled placebo beverage that contained equal calories as the energy drink but provided none of the supplemental vitamins and minerals or active ingredients contained within the energy drink. Because this was not a cross-over design and all drinks–active and placebo–were

Figure 1. Supplement facts and ingredients of the energy drink (Celsius, Celsius, Inc, Delray Beach, Florida, USA). Subjects in EX-A (exercise + Celsius) and NEX-A (Celsius only) consumed 1 energy drink per day for 10 weeks (1/day × 10 weeks), in combination with an ad libitum diet. Subjects in EX-B (exercise + placebo) and NEX-B (placebo only) consumed an identically canned and tasting placebo beverage that contained the same total energy as Celsius but none of the active ingredients or supplemental micronutrients.

identically packaged in unlabeled aluminum cans, subjects and investigators were assumed to have been unaware of the differences between cans labeled "A" or "B."

Exercise Protocol. The exercise program was designed using the American College of Sports Medicine (ACSM) recommended guidelines for apparently healthy adults. All participants received individualized workout cards to track progress, and all participants were supervised and trained by an ACSM or National Strength and Conditioning Association certified strength and conditioning specialist or trainer. Progressive endurance training, on Monark (Monark Exercise AB, Vansbro, Sweden) cycle ergometers, was performed 3 days per week with subjects wearing electronic heart rate monitoring devices to ensure adherence to prescribed percent heart rate reserve (%HRR) exercise intensities. Progression was as follows: Week 1 = 15 to 20 minutes @ 40 to 50%HRR; Week 2 = 20 to 25 minutes @ 40 to 50%HRR; Weeks 3–4 = 25 to 30 minutes @ 50 to 60%HRR; Weeks 5–7 = 25 to 30 minutes @ 60 to 70%HRR; and Weeks 8–10 = 30 to 35 minutes @ 60 to 70%HRR. Resistance training was performed 2 days per week, providing at least 24 hours of recovery between sessions. Participants completed 9 isotonic exercises incorporating both single-joint and multi-joint exercises: Bench press, lat pulldown, seated military press, biceps curl, triceps pushdown, leg press, lying leg curl, low-back extension, and abdominal crunch. Each exercise was performed once per session, with participants completing 8 to 12 repetitions per exercise until volitional fatigue. Weight was increased when participants performed ≥10 repetitions at the same resistance during 2 consecutive lifting sessions.

Nutritional Analyses. All participants were instructed to maintain prestudy, ad libitum dietary habits and asked to provide 3-day food logs during pretesting and each week of testing for a total of 11 weeks of food logs. Each food log included 2 nonconsecutive weekdays and 1 weekend day and was used to represent subjects' average weekly diets. Food logs were analyzed for total energy (kcal), macronutrient, micronutrient, trace element, and caffeine content using Food Processor Version 8.6.0 (ESHA Research, Salem, Oregon, U.S.A.).

Body Composition. Body composition was determined, and test-retest reliability was quantified, as previously described by Lockwood et al. (18), with 1 modification–body volume was measured by hydrostatic weighing as described by Moon et al. (22). All body composition assessments were performed on the same day following a 12-hour fast (water intake was allowed up to 1 hour prior to testing). Hydration status was determined using specific gravity via handheld refractometry (Model CLX-1, precision = 0.001 ± 0.001, VEE GEE Scientific, Inc, Kirkland, Washington, USA) prior to all body composition measurements. Specific gravity values indicated all subjects were properly hydrated during both PRE (1.022 ± 0.007) and POST (1.021 ± 0.007). Fat mass (FM), percent body fat (%FAT), and fat-free mass (FFM)

were estimated using the 5-compartment (5-C) model described by Wang et al. (32):

$$FM \text{ (kg)} = 2.748 \text{ (BV)} - 0.715 \text{ (TBW)} + 1.129 \text{ (Mo)} + 1.222 \text{ (Ms)} - 2.051 \text{ (BM)}$$

$$\%FAT = (FM/BM) \times 100$$

$$FFM \text{ (kg)} = BM - FM$$

where BV is total body volume, TBW is total body water, Mo is total body bone mineral, Ms is total body soft tissue mineral, and BM is body mass.

Dual-energy x-ray absorptiometry (DEXA) (software version 10.50.086, Lunar Prodigy Advance, Madison, Wisconsin, USA) was used to estimate total body bone mineral content and total body muscle mass (MM). Bone mineral content (BMC) was converted to Mo using the following equation: $Mo = \text{total body BMC} \times 1.0436$ (32). The sum of lean soft tissue for both arms and legs (ALST), as measured by DEXA, was used to estimate MM from the validated equation of Kim et al. (16): $MM = (1.13 \times ALST) - (0.02 \times age) + [0.61 \times \text{sex (m = 0, f = 1)}] + 0.97$. Bioimpedance spectroscopy (BIS) was used to estimate TBW following the procedures recommended by the manufacturer (Imp SFB7, ImpediMed Limited, Queensland, Australia) and as previously reported and validated by Moon et al. (25). The TBW estimate then was used to estimate Ms using the equation from Wang et al. (32): $Ms = TBW \times 0.0129$.

Cardiorespiratory Measurements. Blood pressure and resting heart rate were determined after 15 minutes of supine rest using an electronic sphygmomanometer (HEM-773AC, Omron HealthCare Inc, Vernon Hills, Illinois, USA). Subjects then were fitted with an electronic heart rate monitor and escorted to the metabolic lab to perform a 20 W/min ramp peak cardiorespiratory test, as previously described by Rossiter et al. (26), using a Corival 906900 (Lode B.V. Medical Technology, Groningen, The Netherlands) upright cycle ergometer. Respiratory gases were monitored and continuously analyzed with open-circuit spirometry using a calibrated metabolic cart and manufacturer's software (True One 2400, Parvo-Medics, Inc, Provo, Utah, USA). Data were averaged over 15-second intervals, with the highest 15-second oxygen consumption, minute ventilation, and heart rate recorded as the peak oxygen uptake (VO_2peak), peak minute ventilation (VE), and maximum heart rate (HRmax), respectively. Ventilatory threshold (VT) was determined as the steady-state point at which oxygen uptake equaled carbon dioxide expiration. Total time-to-exhaustion (TTE), VO_2 at VT, energy expenditure at VT, and power output at VT also were recorded and used for analyses.

Strength Measurements. After a brief warm-up, each participant completed successive sets of one repetition attempts with increasing loads, allowing 2 to 3 minutes of rest between trials until a 1-repetition maximum (1RM) was achieved for upper- and lower-body strength (bench and incline leg press, respectively).

Clinical Safety Analyses. Prior to exercise testing, during weeks PRE and POST, and following a minimum 12-hour fast and 48-hour abstinence from strenuous exercise, subjects reported to the University Health Center to donate blood and serum. Samples were separated by centrifugation and shipped to Laboratory Corporation of America (Oklahoma City, Oklahoma, USA) for analysis. All samples were assayed for comprehensive metabolic panels and blood lipids, including serum glucose, uric acid, blood urea nitrogen (BUN), creatinine, BUN/creatinine ratio, sodium, potassium, chloride, carbon dioxide, calcium, phosphorus, total protein, albumin, globulin, albumin/globulin ratio, bilirubin, alkaline phosphatase, lactate dehydrogenase, aspartate aminotransferase, alanine aminotransferase, gamma-glutamyl transpeptidase, iron, total cholesterol, triglycerides, high-density lipoprotein (HDL) cholesterol, very low-density lipoprotein (VLDL) cholesterol, low-density lipoprotein (LDL) cholesterol, and LDL/HDL ratio. Whole blood was analyzed for white blood cell counts; red blood cell counts; hemoglobin; hematocrit; mean cell volume; mean corpuscular hemoglobin; mean corpuscular hemoglobin concentration; red cell distribution width; platelets; mean platelet volume; and percent (%) and total (#) lymphocytes, monocytes, and granulocytes.

Qualitative Energy and Mood Assessment. All participants in EX-A and EX-B completed 6 Physical Activity Affect Scale (PAAS) questionnaires over the course of the 10-week training intervention: 1 immediately following the completion of the first aerobic and strength training session (days 1 and 2 of week 2); again at the midpoint of the 10-week training protocol (days 3 and 4 of week 6); and on the last 2 days of exercise training (days 6 and 7 of week 11). PAAS scores were averaged across weeks and were used to assess the influence of the energy drink on subjects' qualitative perception of positive effect, negative effect, fatigue, or tranquility in response to exercise as described by Lox et al. (19).

Statistical Analyses. Separate 2-way repeated measures analyses of variance (ANOVA) [time (PRE vs. POST) × group (EX-A vs. NEX-A vs. EX-B vs. NEX-B)] were used to identify main effects for time and time*group interactions. If a significant interaction was observed, the statistical model was decomposed by examining simple main effects with 1-way repeated measures ANOVAs across groups and 1-way factorial ANOVAs across time. In the event of a simple main effect, Tukey post hoc comparisons were performed among groups; all pair-wise comparison dependent samples *t*-tests with Bonferroni corrections were performed across time ($p \leq 0.0125$). If there was no interaction, main effects were analyzed by collapsing across the noninteracting variable as described earlier for simple main effects. In the event of significant baseline differences of a dependent variable, as determined by multiple 1-way ANOVAs, homogeneity-of-slopes tests to determine the interaction between the covariate and factor were conducted to assess the

appropriateness of analysis of covariance (ANCOVA) analyses; ANCOVAs were not required for this investigation. Using an a priori level of significance of $p \leq 0.05$ and effect size (ES) of 0.40 for between-within interactions for repeated measures ANOVA analysis across 4 groups, statistical power $(1-\beta)$ was determined to be 0.82 and total sample size (N) was equal to 40. The test-retest reliability for the 5-C equation, as measured 24 to 48 hours apart in 11 men and women, resulted in an intraclass correlation (ICC) of 0.99 and a standard error of measurement (SEM) of 0.76%, 0.59 kg, and 0.76 kg for %FAT, FM, and FFM, respectively (33). Test-retest reliability for MM, as measured 24 to 48 hours apart on the same subjects, resulted in an ICC and SEM of 0.99 and 0.04 kg, respectively. The BIS device used in the current study was recently examined in our laboratory as compared to deuterium oxide for estimating TBW in a heterogeneous sample of 28 men and women and demonstrated a nonsignificant constant error (CE = -0.09L; $p > 0.05$) and high correlation ($r = 0.98$) (21). All

ANOVA assumptions were met; analyses were performed using SPSS 15.0 (SPSS Inc. Chicago, Illinois, U.S.A.).

RESULTS

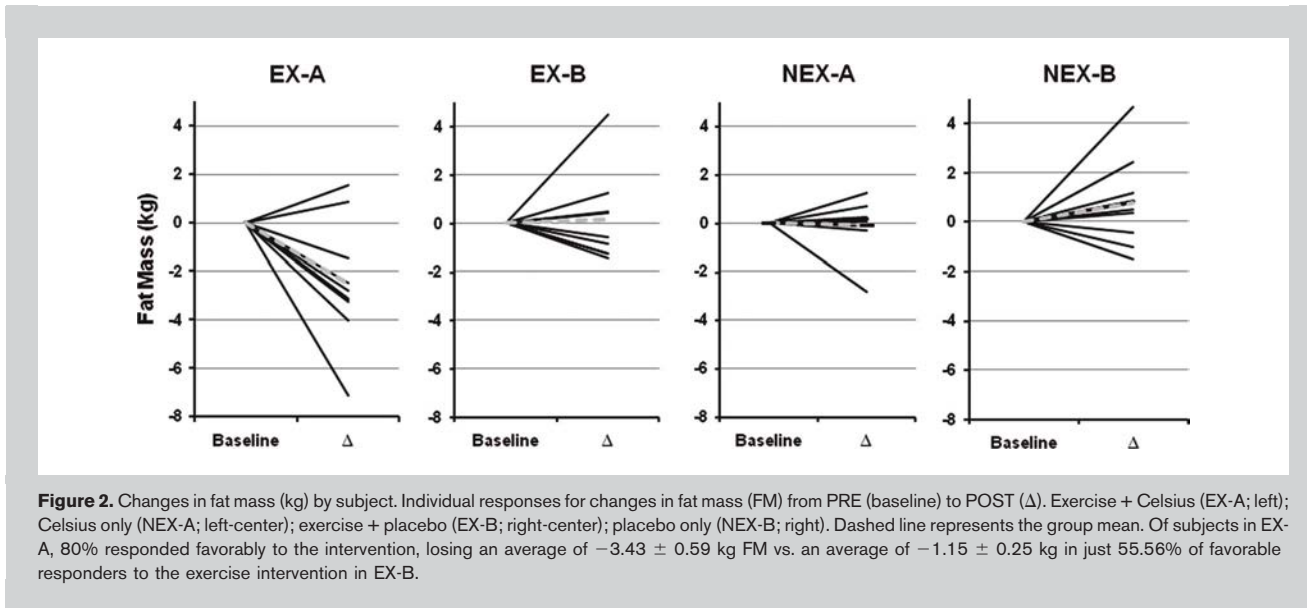### Descriptives and Nutritional Analyses

Baseline measures for age, height, body mass, percent body fat (%FAT), and average energy and caffeine intake did not differ ($p > 0.05$) between groups (Table 1). No significant ($p > 0.05$) interactions or main effects for time were observed for total energy, carbohydrate, protein, % total energy from protein, fat, fiber, sugar, or saturated fat. A significant time*group interaction was observed for % total energy from carbohydrate ($p = 0.019$, ES = 0.218, 1-$\beta = 0.844$). Post hoc analyses revealed a significant difference ($p \leq 0.05$) from PRE to week 5 between EX-A versus EX-B and NEX-B; this difference was not maintained ($p > 0.05$) through week 10. As expected, significant ($p \leq 0.05$) time*group interactions were observed for caffeine. Post hoc analyses, however, revealed only significant differences ($p \leq 0.05$) from PRE to week 5

TABLE 2. Changes in body composition from PRE to POST ($\bar{x} \pm$ SEM).

GROUP	PRE	POST	Δ	%Δ
BODY MASS (kg): Time ($p = 0.394$, ES = 0.022, 1-β=0.134); Time *Group ($p = 0.146$, ES = 0.148, 1-$\beta = 0.450$)				
EX-A	90.51 ± 4.18	88.72 ± 3.71	−1.79 ± 1.05	−2.02
NEX-A	84.89 ± 3.80	84.92 ± 4.04	0.03 ± 0.53	0.04
EX-B	93.86 ± 5.09	93.47 ± 5.15	−0.39 ± 0.67	−0.41
NEX-B	82.13 ± 5.75	82.88 ± 5.72	0.75 ± 0.74	0.91
FAT MASS (Kg): Time ($p = 0.192$, ES = 0.051, 1-$\beta = 0.253$); Time *Group ($p = 0.003$, ES = 0.338, 1-$\beta = 0.916$)				
EX-A	24.60 ± 2.67	22.10 ± 2.32	−2.50 ± 0.77	−11.32*‡§
NEX-A	22.79 ± 2.27	22.70 ± 2.41	−0.09 ± 0.42	−0.42
EX-B	24.58 ± 3.89	24.72 ± 4.01	0.14 ± 0.62	0.57
NEX-B	21.71 ± 2.60	22.49 ± 2.80	0.78 ± 0.56	3.46
FAT-FREE MASS (kg): Time ($p = 0.782$, ES = 0.002, 1-$\beta = 0.058$); Time *Group ($p = 0.412$, ES = 0.082, 1-$\beta = 0.243$)				
EX-A	69.91 ± 2.14	66.63 ± 2.26	0.71 ± 0.53	1.07
NEX-A	62.10 ± 1.95	62.23 ± 2.05	0.13 ± 0.41	0.21
EX-B	69.28 ± 2.16	68.75 ± 2.13	−0.53 ± 0.56	−0.76
NEX-B	60.42 ± 3.56	60.39 ± 3.52	−0.02 ± 0.53	−0.04
% BODY FAT: Time ($p = 0.217$, ES = 0.046, 1-$\beta = 0.231$); Time *Group ($p = 0.002$, ES = 0.350, 1-$\beta = 0.930$)				
EX-A	26.62 ± 1.93	24.50 ± 1.92	−2.12 ± 0.58	−8.64*‡§
NEX-A	26.49 ± 1.66	26.29 ± 1.80	−0.19 ± 0.48	−0.74
EX-B	25.12 ± 2.98	25.41 ± 2.99	0.29 ± 0.48	1.12
NEX-B	25.84 ± 1.76	26.53 ± 2.03	0.69 ± 0.53	2.60
MUSCLE MASS (kg): Time ($p < 0.001$, ES = 0.478, 1-$\beta = 1.000$); Time *Group ($p < 0.001$, ES = 0.460, 1-$\beta = 0.993$)				
EX-A	32.08 ± 0.91	33.71 ± 0.90	1.63 ± 0.22	4.83*†§
NEX-A	30.97 ± 0.55	31.06 ± 0.50	0.09 ± 0.08	0.29
EX-B	33.19 ± 1.26	34.64 ± 1.24	1.45 ± 0.44	4.18*†§
NEX-B	30.90 ± 1.68	30.89 ± 1.67	−0.01 ± 0.27	−0.03

EX-A = exercise + Celsius; NEX-A = Celsius only; EX-B = exercise + placebo; NEX-B = placebo only.
Body composition, as assessed by the 5-compartment (5-C) model; muscle mass, as assessed by DEXA; ES = effect size; 1-β = power.
Main effects for Time and Time*Group interaction at $p \leq 0.05$.
*Different from PRE ($p \leq 0.0125$).
†Different from NEX-A ($p \leq 0.05$).
‡Different from EX-B ($p \leq 0.05$).
§Different from NEX-B ($p \leq 0.05$).

#Data Corrections
-1.98%
 0.04%
-0.41%
 0.92%

#Data Corrections
-7.95%
-0.73%
 1.14%
 2.67%

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# Corrections to Data Tables. It has come to our attention that there are incorrect values published
in the Data Tables of this study. These incorrect values DO NOT influence
the published clinical results. Incorrect values in Tables like this are common place among
scientific journals and may have occurred during the type setting and/or copy editing process.
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Figure 2. Changes in fat mass (kg) by subject. Individual responses for changes in fat mass (FM) from PRE (baseline) to POST (Δ). Exercise + Celsius (EX-A; left); Celsius only (NEX-A; left-center); exercise + placebo (EX-B; right-center); placebo only (NEX-B; right). Dashed line represents the group mean. Of subjects in EX-A, 80% responded favorably to the intervention, losing an average of −3.43 ± 0.59 kg FM vs. an average of −1.15 ± 0.25 kg in just 55.56% of favorable responders to the exercise intervention in EX-B.

between EX-A versus EX-B and NEX-B and from PRE to week 10 for NEX-A compared to EX-B and NEX-B.

Body Composition

Body composition results are presented in Table 2. It is notable that post hoc analyses revealed significantly ($p < 0.05$) greater decreases in FM and %FAT for EX-A (ΔFM = −2.50kg and Δ%FAT = −2.12%, respectively) than EX-B (ΔFM = +0.57kg; Δ%FAT = +0.29%) and NEX-B (ΔFM = +3.46kg; Δ%FAT = +0.69%); EX-A was not significantly ($p > 0.05$) different from changes in NEX-A (ΔFM = −0.42kg; Δ%FAT = −0.20%). Individual response graphs for FM (Figure 2) and muscle mass (Figure 3) reveal less variability among subjects in NEX-A versus NEX-B and an increased responder rate for subjects in

group EX-A versus EX-B. For example, 80% of subjects in EX-A responded favorably to the training intervention, resulting in an average improvement among responders of −3.43 ± 0.59kg FM compared to −1.15 ± 0.25 kg FM in 55.56% of favorable responders in EX-B.

Cardiorespiratory Measurements

Results from peak VO$_2$ testing are presented in Table 3 and reveal significant ($p \leq 0.05$) time*group interaction effects across all variables measured, with the exception of VE and HRmax. PRE to POST measures in EX-B only improved significantly ($p = 0.001$) for TTE, whereas EX-A significantly improved ($p \leq 0.010$) across all dependent variables analyzed, with the exception of HRmax and energy
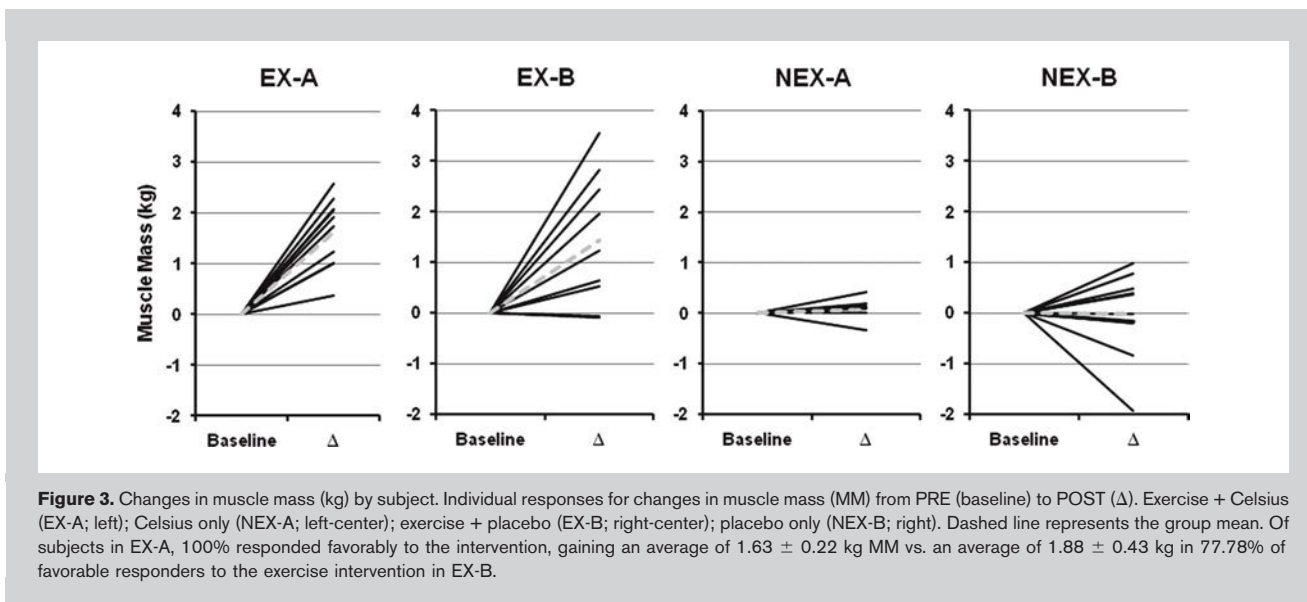

Figure 3. Changes in muscle mass (kg) by subject. Individual responses for changes in muscle mass (MM) from PRE (baseline) to POST (Δ). Exercise + Celsius (EX-A; left); Celsius only (NEX-A; left-center); exercise + placebo (EX-B; right-center); placebo only (NEX-B; right). Dashed line represents the group mean. Of subjects in EX-A, 100% responded favorably to the intervention, gaining an average of 1.63 ± 0.22 kg MM vs. an average of 1.88 ± 0.43 kg in 77.78% of favorable responders to the exercise intervention in EX-B.

TABLE 3. Changes in cardiorespiratory fitness from PRE to POST ($\bar{x} \pm$ SEM).

Group	PRE	POST	Δ	%Δ
TIME-to-EXHAUSTION (sec): Time ($p < 0.001$, ES = 0.680, 1-β = 1.000); Time *Group ($p < 0.001$, ES = 0.684, 1-β = 1.000)				
EX-A	641.90 ± 36.32	786.20 ± 36.93	144.30 ± 14.87	18.35*†§
NEX-A	622.00 ± 24.21	634.25 ± 36.35	12.25 ± 17.28	1.93
EX-B	661.89 ± 35.52	759.00 ± 40.28	97.11 ± 17.40	12.79*†§
NEX-B	615.30 ± 30.62	609.70 ± 30.39	−5.60 ± 9.49	−0.92
HRmax (bpm): Time ($p = 0.537$, ES = 0.012, 1-β = 0.093); Time *Group ($p = 0.247$, ES = 0.116, 1-β = 0.347)				
EX-A	193.80 ± 8.23	111.19 ± 7.40	15.72 ± 2.95	−0.73
NEX-A	85.05 ± 5.89	95.36 ± 6.83	10.31 ± 6.95	1.96
EX-B	89.09 ± 3.22	97.82 ± 4.33	8.73 ± 3.20	−1.64
NEX-B	85.11 ± 4.47	87.44 ± 5.89	2.33 ± 3.97	−1.26
VE (L/min): Time ($p < 0.001$, ES = 0.361, 1-β = 0.987); Time *Group ($p = 0.168$, ES = 0.140, 1-β = 0.423)				
EX-A	95.47 ± 8.23	111.19 ± 7.40	15.72 ± 2.95	14.14*
NEX-A	85.05 ± 5.89	95.36 ± 6.83	10.31 ± 6.95	10.82
EX-B	89.09 ± 3.22	97.82 ± 4.33	8.73 ± 3.20	8.92
NEX-B	85.11 ± 4.47	87.44 ± 5.89	2.33 ± 3.97	2.67
V_{O_2} Peak (L/min): Time ($p < 0.001$, ES = 0.353, 1-β = 0.984); Time *Group ($p < 0.001$, ES = 0.473, 1-β = 0.995)				
EX-A	2.95 ± 0.15	3.40 ± 0.13	0.45 ± 0.06	13.14 *†‡§
NEX-A	2.92 ± 0.11	2.97 ± 0.15	0.05 ± 0.10	1.68
EX-B	3.21 ± 0.14	3.31 ± 0.13	0.09 ± 0.05	2.86
NEX-B	2.94 ± 0.17	2.93 ± 0.19	−0.01 ± 0.06	−0.48
V_{O_2}peak (mL/kg/min): Time ($p < 0.001$, ES = 0.371, 1-β = 0.990); Time *Group ($p < 0.001$, ES = 0.540, 1-β = 1.000)				
EX-A	33.03 ± 1.92	38.79 ± 2.05	5.76 ± 0.60	14.85*†‡§
NEX-A	34.80 ± 1.73	35.33 ± 2.02	0.53 ± 1.25	1.49
EX-B	35.14 ± 2.50	36.38 ± 2.65	1.23 ± 0.58	3.39
NEX-B	36.28 ± 1.46	35.78 ± 1.93	−0.50 ± 0.72	−1.40
VT (min): Time ($p = 0.096$, ES = 0.082, 1-β = 0.384); Time *Group ($p = 0.004$, ES = 0.324, 1-β = 0.897)				
EX-A	5.35 ± 0.35	7.41 ± 0.58	2.06 ± 0.61	27.80*†§
NEX-A	6.10 ± 0.39	5.50 ± 0.59	−0.60 ± 0.41	−10.91
EX-B	7.17 ± 0.66	7.72 ± 0.54	0.56 ± 0.53	7.19
NEX-B	5.39 ± 0.62	5.16 ± 0.44	−0.23 ± 0.46	−4.46
V_{O_2} @ VT (L/min): Time ($p = 0.511$, ES = 0.013, 1-β = 0.099); Time *Group ($p = 0.007$, ES = 0.307, 1-β = 0.870)				
EX-A	1.69 ± 0.08	2.09 ± 0.13	0.40 ± 0.12	19.29*†§
NEX-A	1.82 ± 0.09	1.67 ± 0.14	−0.15 ± 0.09	−9.04
EX-B	2.18 ± 0.18	2.17 ± 0.12	0.00 ± 0.13	−0.15
NEX-B	1.69 ± 0.16	1.60 ± 0.10	−0.10 ± 0.11	−5.95
V_{O_2}(mL/kg/min): Time ($p = 0.401$, ES = 0.021, 1-β = 0.131); Time *Group ($p = 0.006$, ES = 0.311, 1-β = 0.876)				
EX-A	19.09 ± 1.31	23.70 ± 1.37	4.65 ± 1.25	19.54*†§
NEX-A	21.79 ± 1.50	19.90 ± 1.79	−1.88 ± 1.13	−9.46
EX-B	23.63 ± 2.24	23.98 ± 2.10	0.33 ± 1.60	1.45
NEX-B	20.59 ± 1.29	19.74 ± 1.51	−0.83 ± 1.13	−4.25
POWER OUTPUT @ VT (W): Time ($p = 0.110$, ES = 0.076, 1-β = 0.357); Time *Group ($p = 0.004$, ES = 0.328, 1-β = 0.903)				
EX-A	123.50 ± 6.76	164.00 ± 11.60	40.50 ± 12.07	24.70*†§
NEX-A	139.50 ± 8.86	126.25 ± 11.93	−13.25 ± 8.13	−10.50
EX-B	159.89 ± 13.10	171.00 ± 10.84	11.11 ± 10.56	6.50
NEX-B	124.10 ± 12.44	119.60 ± 8.90	−4.50 ± 9.03	−3.76
ENERGY EXPENDITURE @ VT (kcal/min): Time ($p = 0.266$, ES = 0.037, 1-β = 0.195); Time *Group ($p = 0.023$, ES = 0.247, 1-β = 0.743)				
EX-A	8.55 ± 0.45	10.61 ± 0.73	2.06 ± 0.78	19.42†§
NEX-A	9.14 ± 0.51	8.50 ± 0.69	−0.64 ± 0.33	−7.50
EX-B	10.88 ± 1.07	11.22 ± 0.63	0.34 ± 0.63	3.07
NEX-B	8.56 ± 0.86	8.25 ± 0.54	−0.31 ± 0.64	−3.76

EX-A = exercise + Celsius; NEX-A = Celsius only; EX-B = exercise + placebo; NEX-B = placebo only; HRmax = max heart rate; VE = peak minute ventilation; V_{O_2}peak = peak oxygen uptake; VT = ventilatory threshold; ES = effect size; 1-β = power.
Cardiorespiratory fitness and indirect calorimetry, as assessed during 20 W/min ramping bicycle ergometer test to exhaustion.
Main effects for Time and Time *Group interaction at $p \leq 0.05$.
*Different from PRE ($p \leq 0.0125$).
†Different from NEX-A ($p \leq 0.05$).
‡Different from EX-B ($p \leq 0.05$).
§Different from NEX-B ($p \leq 0.05$).

#Data Corrections

17.44%
1.51%
3.51%
−1.38%

#Data Corrections

32.79%
−9.50%
6.95%
−3.63%

Corrections to Data Tables. It has come to our attention that there are incorrect values published in the Data Tables of this study. These incorrect values DO NOT influence the published clinical results. Incorrect values in Tables like this are common place among scientific journals and may have occurred during the type setting and/or copy editing process.
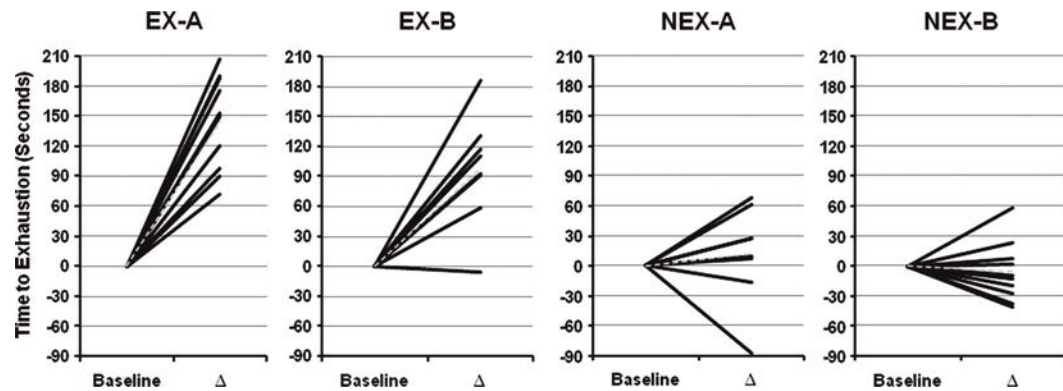
Figure 4. Changes in time-to-exhaustion (sec) by subject. Individual responses for changes in time-to-exhaustion (TTE) from PRE (baseline) to POST (Δ). Exercise + Celsius (EX-A; left); Celsius only (NEX-A; left-center); exercise + placebo (EX-B; right-center); placebo only (NEX-B; right). Dashed line represents the group mean. Of subjects in EX-A, 100% responded favorably to the intervention, increasing TTE an average of 144.30 ± 14.87 seconds vs. an average of 110.00 ± 13.26 seconds in 88.89% of favorable responders to the exercise intervention in EX-B.

expenditure at VT ($p = 0.027$). Also of note, EX-A was significantly different ($p \leq 0.004$) from EX-B for both absolute and relative VO_2peak (Table 3). Individual response graphs for TTE and relative VO_2peak reveal an increased positive responder rate to the intervention and, to a lesser degree, reduced variability among positive responders for subjects in EX-A versus EX-B (Figures 4 and 5).

Strength Measurements

A significant interaction and main effect for time was observed for both 1RM bench and leg press [1RM bench press (time: $p < 0.001$, ES = 0.647, 1-β = 1.000; time *group: $p < 0.001$, ES = 0.575, 1-β = 1.000); 1RM leg press (time: $p < 0.001$, ES = 0.496, 1-β = 1.000; time*group: $p < 0.001$, ES = 0.494, 1-β = 0.997)]. Upper- and lower-body strength improved significantly from PRE to POST for EX-A (+11.64% and +8.14%; $p < 0.001$) and EX-B (+9.54% and +10.72%; $p = 0.001$); upper-body strength significantly improved for NEX-B (+2.58%; $p = 0.011$). Post hoc analyses revealed significant ($p \leq 0.002$) improvements in both upper- and lower-body strength in EX-B versus NEX-A (-0.41% and +1.43%) and NEX-B (+2.58% and -0.66%); improvements in
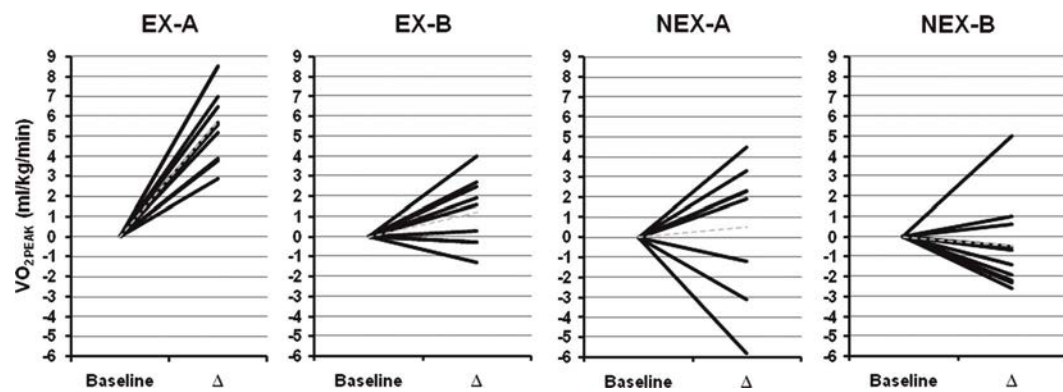

Figure 5. Changes in VO_2peak (mL/kg per minute) by subject. Individual responses for changes in VO_2peak from PRE (baseline) to POST (Δ). Exercise + Celsius (EX-A; left); Celsius only (NEX-A; left-center); exercise + placebo (EX-B; right-center); placebo only (NEX-B; right). Dashed line represents the group mean. Of subjects in EX-A, 100% responded favorably to the intervention, increasing VO_2peak an average of 5.76 ± 0.60 mL/kg per minute vs. an average of 2.17 ± 0.50 mL/kg per minute in just 66.67% of favorable responders to the exercise intervention in EX-B.

TABLE 4. Changes in Clinical Safety Markers from PRE to POST ($\bar{x} \pm$ SEM)†.

	EX-A	NEX-A	EX-B	NEX-B
RESTING HEART RATE (bpm)	−5.50 ± 4.23	4.63 ± 4.32	−5.44 ± 2.18	3.00 ± 3.00
RESTING SYSTOLIC BLOOD PRESSURE (mmHg)	−8.20 ± 4.18	−1.50 ± 2.79	−2.11 ± 2.81	1.00 ± 4.54
RESTING DIASTOLIC BLOOD PRESSURE (mmHg)	−8.60 ± 1.61*	−5.63 ± 3.66	−5.56 ± 2.26	−0.20 ± 2.38
SERUM GLUCOSE (mg/dL)	11.80 ± 4.18	−0.71 ± 3.09	2.11 ± 2.50	3.40 ± 3.47
BUN (mg/dL)	−1.80 ± 0.53*	−0.29 ± 0.84	1.78 ± 1.41	−2.00 ± 1.27
CREATININE (mg/dL)	0.00 ± 0.03	−0.01 ± 0.02	0.09 ± 0.03	0.02 ± 0.01
BUN:CREATININE	−1.70 ± 0.42*	−0.13 ± 0.72	0.44 ± 1.32	−2.30 ± 1.22
POTASSIUM (mM/L)	0.33 ± 0.09*	−0.04 ± 0.15	0.09 ± 0.15	−0.10 ± 0.18
PHOSPHORUS (mg/dL)	−0.35 ± 0.18*§	−0.04 ± 0.14	0.19 ± 0.23	0.54 ± 0.14*
IRON (μg/dL)	10.20 ± 11.43	42.71 ± 15.92‡	−25.78 ± 16.55†	−1.00 ± 17.01
ALANINE AMINOTRANSFERASE (IU/L)	−1.80 ± 2.47	−0.86 ± 4.51	−4.67 ± 1.05*	5.70 ± 3.68
TOTAL CHOLESTEROL (mg/dL)	−19.10 ± 8.87	−0.71 ± 6.32	−10.78 ± 8.73	0.70 ± 7.68
TRIGLYCERIDES (mg/dL)	7.70 ± 20.95	26.71 ± 21.62	−6.00 ± 9.16	9.30 ± 9.82
HDL CHOLESTEROL (mg/dL)	−0.50 ± 1.20	1.57 ± 1.86	−0.44 ± 1.63	1.40 ± 1.63
VLDL CHOLESTEROL (mg/dL)	1.60 ± 4.16	5.43 ± 4.29	−1.22 ± 1.79	1.90 ± 1.96
LDL CHOLESTEROL (mg/dL)	−20.20 ± 7.86	−7.71 ± 7.17	−9.11 ± 8.00	−2.60 ± 5.61
LDL:HDL	−0.52 ± 0.20	−0.24 ± 0.13	−0.09 ± 0.16	−0.13 ± 0.09
MEAN CELL VOLUME (μm³)	1.10 ± 0.23*	0.29 ± 0.36	0.44 ± 0.34	0.50 ± 0.27
MEAN CORPUSCULAR HEMOGLOBIN (pg)	0.72 ± 0.12*	0.49 ± 0.23	0.64 ± 0.26	0.35 ± 0.18
RED CELL DISTRIBUTION WIDTH (%)	0.47 ± 0.14*	0.19 ± 0.41	−0.43 ± 0.07*	−0.25 ± 0.09
MEAN PLATELET VOLUME (μm³)	0.41 ± 0.13*	0.27 ± 0.13	−0.03 ± 0.11	0.16 ± 0.12
% MONOCYTES (%)	0.30 ± 0.50	0.86 ± 0.14*	1.00 ± 0.53	−0.50 ± 0.45

EX-A = exercise + Celsius; NEX-A = Celsius only; EX-B = exercise + placebo; NEX-B = placebo only.
Clinical safety, as assessed by resting cardiac function and fasted blood and serum analysis.
Main effects for Time and Time*Group interaction at $p \leq 0.05$.
*Different from PRE ($p \leq 0.0125$).
†Different from NEX-A ($p \leq 0.05$).
‡Different from EX-B ($p \leq 0.05$).
§Different from NEX-B ($p \leq 0.05$).
Multiple blood and serum assays that yielded no significant between- or within-group effects have been omitted from the table.

EX-A were significantly ($p < 0.001$) greater than both NEX-A and NEX-B for 1RM bench press but only significantly ($p = 0.008$) greater than NEX-B for 1RM leg press.

Clinical Safety Analyses

Select blood and serum analyses are presented in Table 4. With the exception of a nonsignificant increase (+13.20%; $p = 0.020$) in fasted serum glucose from PRE to POST in EX-A, all clinical safety markers measured (including serum glucose) remained within normal fasted reference values for subjects within both energy drink groups. Results indicate an improved metabolic adaptation to exercise or no deleterious effects on hepatic, renal, cardiovascular, or immune function as a result of once-daily energy drink consumption (Table 4). Instead, post hoc analyses revealed a trend ($p = 0.021$) toward greater exercise-induced stress and/or a reduction in adaptation capacity for subjects in EX-B (Table 4); creatinine increased by +7.93%, from PRE to POST, to slightly above the normal range of 0.6 to 1.2 mg/dL. All other fasted clinical safety markers tested, across all groups, were within standard reference ranges. Aside from some verbal reports of restless sleep by subjects within EX-A, no other adverse events were reported by participants consuming the energy drink and no adverse cardiorespiratory events were observed for subjects within the EX-A group during exercise sessions.

Energy and Mood Assessment

No significant ($p > 0.05$) interaction or main effects for time were observed for any of the 4 qualitative dependent variables measured: Positive effect, negative effect, fatigue, and tranquility. Post hoc analyses also revealed no significant differences within or between groups (EX-A and EX-B) across time.

DISCUSSION

Previous findings by Dalbo et al. (9) and Roberts et al. (25) suggest that chronic energy drink (i.e., Celsius) consumption may improve body composition via increased thermogenic and metabolic adaptations, with hemodynamic and blood chemistry effects comparable to placebo. Indeed, Roberts

et al. (25) found a significant reduction in FM in response to 28 days of chronic energy drink consumption vs. placebo. The current study, however, discovered that, when not combined with exercise, the same energy drink as studied by Dalbo et al. and Roberts et al. yielded no appreciable effect on body fat or composition (NEX-A ΔFM = -0.09 ± 0.42 kg) after 10 weeks of daily ingestion. Group differences may explain the variance between study outcomes: Prior level of physical fitness, body mass (Roberts et al. [25] BM = 81.7 $\pm$ 11.3 kg vs. NEX-A BM = 84.89 $\pm$ 3.8 kg) and fat mass (Roberts et al. [25] %FAT = 22.8 $\pm$ 7.3% vs. NEX-A %FAT = 26.49 $\pm$ 1.66%) may predispose one's lipolytic responsiveness to chronic energy drink consumption in the absence of exercise. As evidence, it has been reported that β-adrenergically (β-AR) stimulated lipolysis is impaired in obese vs. lean males (15), α_2-adrenergic (α_2-AR) antilipolytic action is greater in obese as opposed to lean subjects (29), and α_2-AR activation is positively associated with fat cell size (20).

Physiological tolerance ("habituation") as a result of chronic caffeine ingestion and sympathetic nervous system activation, although inconclusive (6,10,13,23), also may explain the apparently confounding results observed between the current study and previous research. For example, Dekker et al. (11) found that, whereas acute caffeine ingestion significantly increased serum free fatty acids (FFA) and epinephrine, there was a significantly decreased response after 14 days of caffeine ingestion. Similarly, Dalbo et al. (9) reported significant increases in FFA appearance up to 180 minutes POST energy drink consumption; however, Roberts et al. (25) found that FFA area under the curve (across 180 minutes postingestion) trended downward from Day 0 to Day 28 despite reporting sustained increases in resting energy expenditure (REE) and glycerol area under the curve. Thus, it is plausible the energy drink alone may increase short-term lipolysis but that decreased stimulation of lipolytic mechanisms may become observable after 28 days of chronic ingestion. If correct, a physiological tolerance and the presence of a refractory period arising between 4 and 10 weeks of chronic ingestion would be required to fully rectify the difference in mean changes for FM observed by Roberts et al. (25) and the NEX-A group of the current study. It is interesting that observance of such a refractory period may be suggestive of a cyclical dosing requirement for such caffeine-containing lipolytic agents to maintain efficacy in sedentary males–an unexplored area of research.

When the energy drink was combined with 10 weeks of progressive resistance and endurance training (EX-A), the lipolytic effects described by Dalbo et al. (9) and Roberts et al. (25) were maintained and a significantly augmented physiological response to the exercise intervention was observed (Tables 2 and 3), notably, in body composition and aerobic capacity. With regard to the latter, it should be emphasized that POST exercise testing occurred a minimum of 72 hours after each subject's final day of the 10-week exercise intervention and, therefore, at least 72 hours after withdrawal from the energy drink. Van Soeren and Graham (31) reported no significant differences in Vo_2max in response to acute caffeine or placebo ingestion following 2 and 4 days of caffeine withdrawal. It cannot, therefore, be ruled out that active ingredient pharmacokinetics affecting fuel oxidation may have attributed to the significant between-group effects for Vo_2peak and VT within the current investigation. Furthermore, observance of a significantly ($p < 0.001$) increased VE and reduced diastolic blood pressure in EX-A support the theory of chronic caffeine ingestion resulting in habituation via up-regulation of adenosine receptors or sensitivity (28). However, if the observed cardiorespiratory and health measures were solely the result of delayed clearance rates of energy drink actives or from habituation, significant changes within NEX-A and/or nonsignificant differences between EX-A and NEX-A would be expected.

It is noteworthy that in the absence of dietary intervention, exercise alone (EX-B) provided no appreciable benefit on measures of cardiorespiratory fitness or body fat reduction. Instead, EX-B only realized significant improvements on measures of anaerobic fitness, muscle mass, and strength. King et al. (17) proposed that compensatory events in response to exercise-induced increases in energy expenditure may largely explain nonsignificant changes in body composition from exercise-only interventions. For example, β-AR–mediated lipolysis, such as occurs during exercise-induced catecholamine activation, has been shown to be impaired in obese vs. lean men (15). Similarly, activation of α_2-AR has previously been shown to be up-regulated in obese males in response to exercise and thus has been postulated as contributing to the failure of an exercise-only program at eliciting fat loss (29). Therefore, it is plausible that, whereas the aforementioned mechanisms antagonized lipolysis in EX-B, addition of the energy drink may have increased lipolytic mechanisms via augmented β-AR activation and/or antagonism of α_2-AR antilipolytic response. To the best of our knowledge there are no human data to support α_2-AR antagonism arising from any of the ingredients contained within the energy drink tested. Sympathomimetics within the energy drink (caffeine, green tea, and guarana) may, however, explain any improved β-AR sensitivity (31).

Cumulative thermogenesis–supported by previous work on the current energy drink (9,25) and in similar research involving green tea–containing formulations (3,4,27,34)–also may explain the significant reduction in FM observed in EX-A. However, the aforementioned data cannot adequately address the improvements observed in cardiorespiratory function in EX-A. Instead, improved exercise recovery and immune function in response to antioxidant properties of green tea (30) or taurine (36), supplemental vitamins and minerals, or indirect effects of caffeine on lymphocyte trafficking (5) may have contributed to the significant between- and within-group effects observed. For example, 6 g/day $\times$ 7-day taurine significantly increased Vo_2max and TTE and significantly decreased markers of exercise-induced oxidative

damage to DNA–an effect the authors contributed to the cell-stabilizing properties of taurine (36). In fact, taurine previously has been reported as providing a significant hyperpolarizing (characterized by an increase in K^+ efflux) effect on guinea-pig cardiomyocytes and possibly contributing to a reduction in intracellular $[Ca^{2+}]$ via antagonism of α-AR activation (12). If such occurs in humans, antagonism of α-AR would, as discussed previously, help explain the greater fat loss in EX-A versus EX-B. Additionally, an improved rate of recovery from high $[Ca^{2+}]_{ic}$ also would provide support for the significant cardiorespiratory improvements observed in EX-A and possibly explain the group's significant increase in POST fasting plasma $[K^+]$ (+8.35%; $p = 0.004$). Whether such physiological responses occur in humans and at the taurine dose provided within the current investigation (1 g/day) is entirely speculative, however.

Last, measures of energy drink safety on hepatic, renal, cardiovascular, and immune function, as assessed by PRE and POST blood work and blood pressure analysis, resulted in no assayed variables deviating outside established, normal fasted reference ranges for healthy adults. Specifically, measures either were generally improved (e.g., significant reduction in diastolic blood pressure and BUN:creatinine ratio in EX-A) or not significantly different from placebo, with the exception of a trend toward an increase in fasting serum glucose in EX-A (+13.2%; $p = 0.020$). If causal, one explanation may be that the energy drink impairs lipolytic signaling within the liver and muscles, preventing ectopically stored fat from being oxidized, as postulated by Yang and Smith (35). However, if the aforementioned could indeed explain the increase in serum glucose, then a similar result would have been expected in NEX-A, as would higher blood triglycerides across both energy drink groups. Instead, the increase in fasting serum glucose is believed to be an adaptation to caffeine and/or β-AR agonists promoting an increase in hepatic glucose turnover (14) in response to sympathetic nervous system activation (i.e., fasting). In support, previous research has shown that caffeine ingestion results in increased blood (lactate⁻) arising from nonexercising muscle and that coingestion of caffeine and carbohydrate significantly increases the rate of muscle glycogen resynthesis in response to an exhaustive exercise bout (24). However, until further research is available, it may be prudent that persons with clinical glucose metabolism deficiency abstain from chronic energy drink consumption prior to strenuous physical activity.

In summary, these findings (a) are the first to report long-term safety of chronic ingestion of a commercially available energy drink when consumed alone or in combination with exercise, and (b) both refute and support previous work by Dalbo et al. and Roberts et al. Demonstrating that, in the absence of energy restriction or other dietary controls, chronic ingestion of once-daily Celsius for 10 weeks provides no appreciable benefit on measures of body composition, cardiorespiratory fitness, or strength. However, when ingested preworkout, the energy drink significantly improves physiological adaptations to combined aerobic and resistance training in previously sedentary, overweight men.

PRACTICAL APPLICATIONS

At a practical level, the drink appears to be well tolerated and does not elicit any adverse events beyond some reported incidences of troubled sleep, either when consumed alone or when ingested once daily for 10 weeks and combined with regular exercise. It is surprising that, despite prior data that have shown the tested beverage to elicit increases in resting energy expenditure and free fatty acids when consumed acutely or for 28 days (9,25), the current study found no benefit on measures of body composition in subjects that just consumed the drink for 70 days. However, when the energy drink was consumed daily and combined with, and ingested 15 minutes prior to, exercise, significant improvements in body composition and cardiorespiratory fitness were observed. More interesting is that the observed changes occurred despite no modifications being made to the subjects' diets, there were no significant differences between groups for total caloric intake, and total aerobic training volume between the 2 exercise groups allowed for minimal variance. Thus, it could be suggested that consuming Celsius prior to regular exercise in previously sedentary, overweight men may yield more significant body composition and cardiorespiratory improvements than exercise alone.

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