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Original Article

Effects of Resistance Training and *Paullinia cupana* Supplementation on Body Composition, Liver Enzymes, Lipid Profile, and Inflammation in Overweight Young Women: A Randomized Controlled Trial

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Abstract

Introduction: Overweight is a metabolic, cardiovascular, and inflammatory disorder. This study examined the effects of training with *Paullinia cupana* on anthropometric indices, liver enzymes, lipid profile, and C-reactive protein (CRP) in overweight women.

Methods: Overweight women residing in Qom (Iran), with a body mass index (BMI) of 25–30 kg/m² and body fat percentage > 35% were screened for eligibility. Using the Fisher–Yates shuffle algorithm, 32 participants were randomly assigned in a 1:1:1:1 ratio to resistance training (RT), RT + *P. cupana*, *P. cupana*, and control groups. The intervention, RT, and *P. cupana* supplementation (300 mg, 30 minutes before exercise) were administered, and the primary outcome was BMI. Secondary outcomes included liver enzymes, lipid profile, and CRP. One-way ANOVA and paired t-tests were used for data analysis.

Results: Significant group × time effects were observed for body weight ($P=0.01$), BMI ($P=0.01$), aspartate aminotransferase (AST; $P=0.01$), alanine aminotransferase (ALT; $P=0.02$), alkaline phosphatase (ALP; $P=0.03$), total cholesterol ($P=0.01$), low-density lipoprotein cholesterol (LDL-C; $P=0.01$), triglycerides ($P=0.01$), and high-density lipoproteïne cholesterol (HDL-C; $P=0.01$). In the RT + *P. cupana* group, body weight decreased from 73.5 ± 5.8 to 68.8 ± 4.7 kg, BMI from 27.8 ± 1.3 to 26.2 ± 1.2 kg/m², AST from 22.7 ± 2.8 to 19.0 ± 2.4 U/L, ALT from 19.9 ± 2.4 to 17.8 ± 2.1 U/L, ALP from 72.9 ± 8.0 to 68.8 ± 7.0 U/L, total cholesterol from 191.7 ± 15.0 to 180.0 ± 13.5 mg/dL, LDL-C from 115.5 ± 11.0 to 104.5 ± 9.5 mg/dL, and triglycerides from 135.5 ± 12.9 to 122.0 ± 11.0 mg/dL. However, HDL-C increased from 48.7 ± 4.9 to 54.0 ± 4.2 mg/dL.

Conclusion: Our findings underscore the importance of combining exercise with natural bioactive supplements to prevent metabolic and cardiovascular disorders.

Keywords: Exercise, *Paullinia cupana*, Overweight, Lipids, C-reactive protein

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Introduction

Obesity is a complex metabolic disorder characterized by chronic low-grade inflammation and is particularly prevalent among sedentary women due to hormonal fluctuations and reduced metabolic rate. In this context, adipose tissue functions as an active endocrine organ that secretes pro-inflammatory adipocytokines, thereby contributing to increased production of C-reactive protein (CRP), an important marker associated with cardiovascular and metabolic diseases (1,2). In addition, excessive accumulation of free fatty acids in the liver promotes oxidative stress and hepatocellular damage, resulting in elevated serum aspartate aminotransferase (AST), an indicator of hepatic dysfunction and non-alcoholic fatty liver disease (3). Therefore, interventions that can improve inflammatory status and liver health are of considerable clinical importance (4).

Likewise, obesity is associated with unfavorable changes in body composition and lipid metabolism. Moreover, increased adiposity contributes to insulin resistance, dyslipidemia, and metabolic disturbances that elevate the risk of cardiovascular disease (5). These abnormalities are frequently more pronounced in sedentary women, emphasizing the significance of interventions aimed at improving body composition and metabolic health (6).

Specifically, resistance training (RT) has received considerable attention because of its beneficial effects on muscle hypertrophy, insulin sensitivity, and metabolic regulation. Controlled muscle contractions stimulate metabolic remodeling and the release of anti-inflammatory myokines, possibly inhibiting pro-inflammatory signaling pathways and contributing to improved metabolic health (7). Furthermore, improvements in body composition may reduce metabolic stress on the liver and provide protective effects against hepatic damage (8). However, findings regarding the effects of exercise on body composition, liver enzymes, lipid profiles, and inflammatory markers remain inconsistent. Some studies have reported remarkable improvements, whereas others have found no significant changes, suggesting that responses may depend on exercise

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intensity, intervention duration, and participants' baseline characteristics (9).

In the field of liver enzymes and inflammation, evidence concerning RT is also conflicting. While some studies have reported reductions in inflammatory markers and improvements in liver enzyme profiles, others have demonstrated no significant effects, suggesting that factors such as diet, habitual physical activity, and initial body composition may exert a stronger influence on these outcomes (10). These inconsistencies make it difficult to determine the independent contribution of RT to metabolic health (7).

Paullinia cupana has also attracted attention as a natural supplement with potential metabolic and anti-inflammatory properties. According to some studies, it has favorable effects on lipid profiles and inflammatory markers, whereas others have observed limited or no significant changes (11). Thus, findings regarding the effects of this natural supplement on liver enzymes remain inconclusive and appear to be influenced by dosage, duration of supplementation, and participant characteristics (12).

Despite numerous studies separately examining RT and *P. cupana*, evidence regarding their combined effects remains limited (13). Although these interventions may influence body composition, liver enzymes, lipid profiles, inflammatory markers, and muscle strength, findings in overweight women remain contradictory and difficult to generalize. Therefore, further controlled studies should clarify the potential synergistic effects of RT and *P. cupana* supplementation on body composition, liver enzymes, lipid profiles, inflammatory markers, and muscle strength in this population (14).

Accordingly, the present study aims to examine the combined effects of RT and *P. cupana* supplementation on body composition, liver enzymes, lipid profile, inflammatory markers, and muscle strength in overweight sedentary women.

Materials and Methods

Participants and Study Design

This study was a randomized controlled trial with a parallel-group design including four groups: control, RT, *P. cupana* supplementation, and combined RT plus *P. cupana* supplementation. In addition, the target population consisted of physically inactive women residing in Qom, Iran, aged 18–45 years, with a body mass index (BMI) between 25 kg/m² and 30 kg/m² and body fat percentage above 35%.

Sampling Method and Process

Using convenience sampling, participants were recruited from local sports clubs and community centers in Qom between July 1, 2023, and September 11, 2023. A total of 230 women were initially screened through face-to-face interviews and preliminary assessments for eligibility based on the predefined inclusion and exclusion criteria (e.g., no regular exercise in the past 6 months, no chronic diseases, lack of taking supplements affecting metabolism, and the like). Of these, 72 women met the eligibility criteria. Ultimately, 32 eligible participants who provided written informed consent were enrolled and completed baseline assessments.

Sample Size Calculation

The sample size was determined using G*Power software (version 3.1) based on an a priori power analysis for a repeated-measures analysis of variance (ANOVA; within-between interaction) with power = 0.80, $\alpha = 0.05$ (two-tailed), and an effect size of f = 0.35 (derived from previous similar studies on RT and herbal supplementation in overweight women; for instance, reported mean ± standard deviation changes in body fat percentage of 2.8 ± 1.9% in the intervention group vs. 0.4 ± 1.2% in the control) (7). This calculation indicated that a total of 28–32 participants (7–8 per group) would be sufficient, accounting for a possible 10–15% dropout rate (Figure 1).

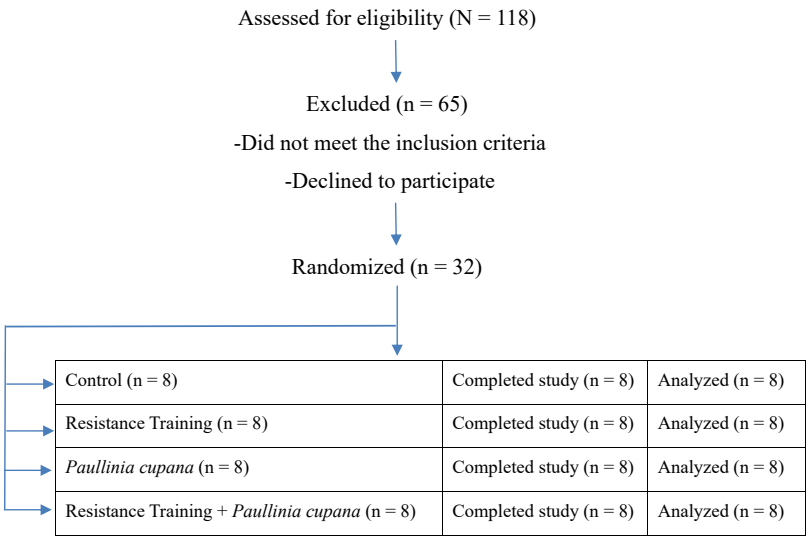

Figure 1. CONSORT Diagram Showing Recruitment, Randomization, and Completion of Participants
Note. CONSORT: Consolidated Standards of Reporting Trials

Randomization and Allocation Concealment

Following baseline assessments, participants were randomly allocated in a 1:1:1:1 ratio to the four groups (RT, RT+G, G, and control; n = 8 per group). Randomization was performed using the Fisher-Yates (Fisher-Yates shuffle) time-dependent randomization algorithm implemented in excel. It should be noted that this method shuffles the allocation sequence while incorporating a time-dependent element in order to enhance randomness while minimizing selection bias.

Allocation concealment was ensured by an independent researcher not involved in recruitment, assessment, or intervention. Moreover, the allocation sequence was placed in sequentially numbered, opaque, sealed envelopes, which were opened only after the completion of baseline assessments.

Blinding

Due to the nature of the interventions, participants and exercise trainers could not be blinded to group allocation. However, outcome assessors and laboratory analysts were blinded to group assignments to reduce detection bias. In addition, statistical analyses were conducted by a researcher who remained unaware of group allocation codes until the completion of the primary analyses.

Participants were randomly assigned to one of the four study groups using a computer-generated randomization sequence prepared by an independent researcher not involved in the intervention or assessment. Additionally, allocation concealment was ensured by placing group assignments in sealed opaque envelopes, which were opened only after the completion of baseline assessments.

The inclusion criteria included age 20–30 years, regular menstrual cycles, absence of hormonal disorders, lack of chronic diseases, absence of use of contraceptives or weight loss drugs, lack of regular physical activity, and willingness to comply with the study protocol. However, the exclusion criteria were unwillingness to cooperate, physical injuries, smoking, and use of drugs, sports, and herbal supplements.

Anthropometric and Body Composition Measurements

Height was measured using a fixed stadiometer (Fisco, Japan) with participants standing barefoot in an upright posture, head in the Frankfurt plane, and feet evenly distributed (with an accuracy of 0.1 cm). Other anthropometric indices and body composition, including body weight, BMI, body fat percentage, fat mass, and lean mass, were estimated using a bioelectrical impedance analysis (BIA, InBody 720 Body Analyzer, InBody Company, Ltd., Seoul, South Korea). This device recorded body weight with an accuracy of 0.1 kg and other body composition indices based on multifrequency impedance. To reduce measurement errors, subjects refrained from strenuous physical activities for at least 12 hours before the test and refrained from eating and drinking for 3–4 hours before the measurement. Likewise, they were asked to avoid caffeine and dietary supplements for 24 hours before the test. All measurements were performed between 7 a.m. and 8 a.m. and under identical environmental conditions in order to minimize the effects of fluctuations in hydration and circadian rhythm.

Outcomes

The primary outcome of the study encompassed changes in body composition, including body weight and BMI. Secondary outcomes included liver enzyme levels, lipid profile parameters (total cholesterol [TC], low-density lipoproteïne cholesterol [LDL-C], high-density lipoproteïne cholesterol [HDL-C], and triglycerides [TG]), and CRP. All outcomes were measured at baseline and after the 8-week intervention period.

Resistance Training Protocol

Upper and lower body strength was assessed using 1-repetition maximum (1RM) tests for bench press and leg press, respectively. The RT program consisted of 8 weeks, 3 sessions per week, each lasting 80 minutes, including 10 exercises (leg press, leg extension, leg curl, calf raise, bench press, seated row, biceps curl, triceps extension, shoulder press, and rowing cable) performed in 3 sets of 5–12 repetitions. Further, training intensity was set at 70% of pre-test 1RM, and 1RM was re-evaluated every two weeks to adjust load. Furthermore, each session included 8 minutes of warm-up and 7 minutes of cool-down stretching. Control participants were also instructed to maintain their usual daily activities and refrain from structured exercise throughout the study period.

Moreover, the RT protocol was conducted over 8 weeks, with 3 sessions per week. Each session lasted approximately 80 minutes, including 8 minutes of warm-up and 7 minutes of cool-down stretching. Additionally, training intensity was set at 70% of 1RM, with 1RM reassessed biweekly to adjust loads. Exercises targeted both upper and lower body muscle groups (13). Related data are provided in Table 1.

Paullinia cupana Supplementation

The supplement used in this study was *P. cupana* in the form of oral capsules. It was prepared from the Solaray *P.*

Table 1. Resistance Training Program

Exercise (Machine/ Equipment)	Muscle Group	Sets	Repetitions	Intensity (%1RM)	Rest (Second)
Leg Press	Quadriceps, Glutes	3	12	70	90
Leg extension	Quadriceps	3	10	70	60
Leg curl	Hamstrings	3	10	70	60
Calf raise	Calves	3	15	60	45
Bench press	Pectorals	3	10	70	90
Seated row	Latissimus, back	3	12	70	60
Biceps curl	Biceps	3	12	60	45
Triceps extension	Triceps	3	12	60	45
Shoulder press	Deltoids	3	10	65	60
Rowing cable	Back/Lats	3	12	70	60

Note. 1RM: 1-repetition maximum

cupana Seed Extract 300 mg (USA), which has a quality standard and standardized extract of *P. cupana* seeds. Each capsule contained 300 mg of the standardized dry extract of *P. cupana* with a content of the main active ingredient, including methylxanthines, especially natural caffeine, of about 10–12%.The subjects were required to take it daily at 8:30 a.m. with a glass of water, on training days, about 30 minutes before the start of the training session, and on non-training days, at the same fixed time daily (14). The *P. cupana* and placebo capsules were completely similar in shape, color, size, and packaging in order to maintain blinding of the study. In addition, the placebo contained inactive ingredients (edible starch) but no bioactive compounds. It should be noted that the supplement and placebo were randomly allocated to the groups. During the intervention period, participants were asked to refrain from taking other dietary supplements, caffeinated beverages (e.g., coffee, strong tea, and energy drinks), and similar herbal products. Subjects' adherence to supplement intake was monitored by daily consumption records and inspection of return packages. The main active ingredient of *P. cupana*in this product is methylxanthines (mainly natural caffeine), along with polyphenolic compounds and tannins. Given the diversity of the chemical compounds of *P. cupana* and their differences in commercial products, a standardized extract supplement was used in this study to minimize fluctuations in the amount of active ingredients.

Participants were monitored for any adverse effects, such as palpitations, insomnia, or gastrointestinal discomfort throughout the study. No serious adverse events were reported.

Maximal Strength Assessment

Maximal strength was estimated using the 1RM based on submaximal lifts (< 10 repetitions) according to the Brzycki equation:

1RM (kg) = weight lifted (kg) / (1.0278 - 0.0278 × number of repetitions)

Participants performed each exercise with proper warm-up and technique, completing repetitions to volitional fatigue without exceeding 10 repetitions. The weight lifted and the number of repetitions was recorded, and 1RM was subsequently calculated using the Brzycki formula.

Details of the procedure are as follows:

Warm-up: Participants completed a standardized 5–10-minute warm-up including light aerobic activity and 1–2 sets of the target exercise with low resistance.

Exercise Selection: Major lifts included specify exercises, e.g., bench press, squat, or leg press.

Rest Intervals: Participants rested 2–3 minutes between sets to minimize the effect of fatigue on submaximal lifts.

Safety: A certified instructor supervised all tests in order to ensure proper form and minimize the risk of injury.

Data Recording: The exact weight lifted and the number of repetitions performed for each exercise was recorded, and 1RM was calculated using the Brzycki formula.

Laboratory Assessments

Fasting venous blood samples were collected from the antecubital vein of participants 48 hours before the first exercise session (pre-test) and 48 hours after the final session (post-test) in order to minimize the acute effects of exercise and ensure baseline metabolic stability. Participants were instructed to fast for 10–12 hours, avoid strenuous physical activity, and refrain from caffeine and alcohol prior to each blood draw. Approximately 5 mL of blood was collected into clot-activator tubes. The samples were allowed to clot at room temperature for 30 minutes, and then centrifuged at 3,000 rpm for 10 minutes at 4°C to separate serum, which was carefully aliquoted into 1.5 mL labeled microtubes and stored at −80°C until analysis. The primary outcome was changes in body composition (fat percentage and muscle mass). Secondary outcomes encompassed changes in liver enzymes, lipid profile, and an inflammatory marker.

Serum CRP was measured using a commercial enzyme-linked immunosorbent assay kit (Pars Azmoon, Iran, Catalog No.: PA-CRP-101, Serial No.: S/N 20231001) with a detection range of 0.1–50 mg/L and sensitivity of 0.05 mg/L. Liver enzymes, including AST and alanine aminotransferase (ALT), were estimated using commercial kits (Pars Azmoon, Iran, Catalog No.: PA-AST-205 and PA-ALT-206, Serial No.: S/N 20231015 and S/N 20231016) according to the IFCC method and reported in U/L.

Lipid profile parameters, including TC, TG, LDL-C, and HDL-C, were determined using commercial kits (Pars Azmoon, Iran; Catalog No.: PA-TC-301, PA-TG-302, PA-LDL-303, PA-HDL-304; Serial No.: 20231021–20231024) with enzymatic colorimetric methods and reported in mg/dL.

All samples were analyzed in duplicate, and mean values were reported accordingly. Quality control samples at low, medium, and high concentrations were included in each analytical batch to verify accuracy and precision. Additionally, intra-assay and inter-assay coefficients of variation (CV) were recorded as CRP < 8% and < 10%, AST and ALT < 5% and < 7%, and lipid parameters < 5% and < 8%, respectively.

All analyses were conducted by trained laboratory personnel blinded to group allocation to minimize measurement bias. Environmental conditions, including room temperature, humidity, and timing of analysis, were kept consistent for all samples in order to reduce pre-analytical variability. Finally, hemolyzed, lipemic, or icteric samples were excluded from analysis and, if possible, recollected for accurate measurement.

Statistical Analysis

Data were analyzed using SPSS, version 26. Normality was assessed with the Shapiro-Wilk test and homogeneity of variance with Levene's test. Values are presented as means ± standard deviations (SD). Between-group comparisons (post-intervention values) were analyzed using one-way ANOVA. Furthermore, within-group comparisons (pre vs. post changes within each group) were

performed using paired t-tests, and mean differences and 95% confidence intervals (95% CI) for pre-changes to post-changes are presented as well ($P<0.05$).

Results

Anthropometric indices, body composition, liver enzymes, lipid profile and CRP were measured pre-test and post-test in the 4 groups (Table 2).

Values are presented as Mean ± SD. P-values in the last column represent between-group comparisons (ANOVA) for post-intervention values. Within-group p-values (pre vs. post comparisons within each group) were calculated using paired t-tests and are reported in the respective rows. Mean differences and 95% confidence intervals (CI) for pre- to post-changes are also presented.

At baseline, participants in all four groups were similar with respect to age, height, weight, BMI, liver enzymes including AST, ALT, and alkaline phosphatase (ALP), lipid profile (TC, LDL, HDL, TG), and CRP. One-way ANOVA showed no significant differences between groups for any variable ($P>0.05$), confirming that the groups were homogeneous at the start of the study. Similarly, liver enzyme levels and lipid profile parameters were comparable across all groups. Following the 8-week intervention, however, significant differences were observed among the four groups in body weight, BMI, liver enzymes, lipid profile and CRP. Participants in the RT and training + *P. cupana* groups demonstrated notable reductions in weight and BMI compared to the control group (with *P*-values <0.05). The *P. cupana* only group showed minimal changes, remaining similar to the control (Table 2). Moreover, liver function improved in the intervention groups. AST decreased in the RT group and in the combined group, and ALT declined compared to controls ($P<0.05$). ALP levels followed a similar pattern, with the greatest reductions observed in the combined group.

Based on the results, significant improvements were observed in the lipid profile. TC decreased in the RT group and in the training + *P. cupana* group. LDL decreased. HDL increased in the RT group and the combined group. However, TG were reduced in these groups, respectively ($P<0.05$). The *P. cupana* only group exhibited minor changes across lipid parameters, remaining largely comparable to the control group. The results indicated that RT, alone or combined with *P. cupana* supplementation, effectively improves body composition, liver enzyme activity, and lipid metabolism in overweight young women. The additive effect of *P. cupana* appeared most evident when combined with RT.

Baseline measurements revealed no significant differences among the groups in terms of anthropometric indices, liver enzymes (AST, ALT, and ALP), lipid profile parameters (TC, LDL, HDL, and TG), or CRP ($P>0.05$), confirming the homogeneity of groups at the start of the study. Normality was assessed with the Shapiro-Wilk test, and homogeneity of variance was checked using Levene's test; both tests were non-significant, indicating that the data were normally distributed and variances were homogeneous ($P>0.05$). Using Tukey's post hoc test, a significant difference was identified between the groups. Tukey's test demonstrated that significant improvements in anthropometric and biochemical outcomes. Overall, the positive effects on body composition liver enzymes and lipid profile were primarily driven by resistance training, either alone or in combination with *P. cupana* supplementation (Table 3).

Discussion

The findings of the present study demonstrated significant reductions in body weight and BMI after 8 weeks in the RT and RT plus *P. cupana* groups, whereas the control and *P. cupana* only groups showed no meaningful changes. These findings are consistent with those of previous research, implying that RT reduces fat mass, increases lean body mass, and improves overall body composition (15). *P. cupana* supplementation appeared to slightly enhance these effects, likely due to its caffeine and bioactive compounds, which can increase energy expenditure and fat oxidation. In contrast, Kennedy et al found that RT was not sufficient in duration or intensity, reporting minimal changes in body composition and related biomarkers, highlighting the importance of training dose and progression (16). Regarding liver enzymes (AST, ALT, and ALP), resistance training, both alone and combined with *P. cupana* supplementation, resulted in significant reductions compared to the control and *P. cupana* only groups. These findings indicate improved liver function and reduced hepatic stress, which is particularly important for overweight individuals at risk of non-alcoholic fatty liver disease (17). Accordingly, the combination of exercise and *P. cupana* exerts synergistic effects, as physical activity enhances hepatic metabolism, and *P. cupana*'s bioactive compounds provide antioxidant and anti-inflammatory benefits (18). Likewise, van der Windt et al concluded that the critical role of physical activity in modulating liver enzyme levels is possibly due to reductions in visceral fat, enhanced insulin sensitivity, and decreased systemic inflammation (19). It is noteworthy that *P. cupanamay* exerts some protective effects on metabolic and inflammatory pathways, particularly under lipotoxicity and hyperlipidemia conditions (20). Significant improvements were observed in the lipid profile of the RT and RT plus *P. cupana* groups, with reductions in TC, LDL, and TG, but increases in HDL. These results align with previous evidence showing that resistance exercise positively modulates lipid metabolism, likely through increased lipoprotein lipase activity and enhanced fat oxidation (21). *P. cupana* supplementation may further support these effects by increasing energy expenditure and improving fatty acid mobilization (22). Similarly, Wassef et al demonstrated that combining RT with *P. cupana* produced the greatest improvements, indicating a potential synergistic effect on cardiovascular risk factors, lipid digestion, and absorption (23). *P. cupana* extracts can inhibit pancreatic lipase activity and reduce cholesterol micellar solubilization, potentially decreasing intestinal cholesterol absorption (24). Moreover, Qadir et al showed consistent

Table 2. Baseline Characteristics of Participants and Post-Intervention Outcomes and Results of One-Way ANOVA

Variable	Control	RT	Paullinia cupana	RT + Paullinia cupana	*P*-Value (Between-Group)
Age (years)	25.3 ± 2.4	24.8 ± 3.1	25.6 ± 2.7	25.1 ± 2.9	0.82
Height (cm)	162.4 ± 4.5	161.9 ± 3.8	163.1 ± 4.2	162.6 ± 3.9	0.74
Weight (kg)					
Pre	73.2 ± 5.1	72.8 ± 6.0	74.1 ± 5.5	73.5 ± 5.8	0.87
Post	73.2 ± 5.1	70.0 ± 5.3	73.5 ± 5.0	68.8 ± 4.7	0.01*
Mean difference	0	2.8 ± 1.3	0.5 ± 1.4	4.7 ± 1.1	-
95% CI	83.2 to 63.2	80.39 to 59.61	74.18 to 72.32	78.6 to 59	-
Within-group *P*-value	0.99	< 0.001	0.32	< 0.001	-
BMI (kg/m²)					
Pre	27.8 ± 1.5	27.7 ± 1.6	27.9 ± 1.4	27.8 ± 1.3	0.95
Post	27.8 ± 1.5	26.7 ± 1.4	27.9 ± 1.4	26.2 ± 1.2	0.01*
Mean difference	0	1.0 ± 0.2	0	1.6 ± 0.1	-
95% CI	30.74 to 24.86	29.44 to 24.04	30.64 to 25.16	28.55 to 23.85	-
Within-group *P*-value	0.98	< 0.001	0.91	< 0.001	-
AST (U/L)					
Pre	22.5 ± 3.2	21.8 ± 2.9	23.0 ± 3.1	22.7 ± 2.8	0.89
Post	22.7 ± 3.0	19.5 ± 2.5	22.9 ± 3.2	19.0 ± 2.4	0.01*
Mean difference	0.2 ± 0.2	2.3 ± 0.4	0.1 ± 0.1	3.7 ± 0.4	-
95% CI	25.64 to 19.76	24.4 to 14.6	29.17 to 16.63	23.7 to 14.3	-
Within-group *P*-value	0.41	< 0.001	0.68	< 0.001	-
ALT (U/L)					
Pre	19.8 ± 2.5	20.2 ± 2.7	20.0 ± 2.6	19.9 ± 2.4	0.91
Post	20.0 ± 2.4	18.0 ± 2.0	19.8 ± 2.5	17.8 ± 2.1	0.02*
Mean difference	-0.2 ± 0.1	2.2 ± 0.7	0.2 ± 0.1	2.1 ± 0.3	-
95% CI	24.70 to 15.3	21.92 to 14.08	24.7 to 14.9	21.92 to 13.68	-
Within-group *P*-value	0.22	< 0.001	0.45	< 0.001	-
ALP (U/L)					
Pre	72.5 ± 8.1	71.8 ± 7.5	73.2 ± 7.8	72.9 ± 8.0	0.93
Post	72.9 ± 8.0	69.5 ± 7.2	73.0 ± 7.8	68.8 ± 7.0	0.03*
Mean difference	-0.4 ± 0.1	2.3 ± 0.3	0.2	4.1 ± 1.0	-
95% CI	88.58 to 57.22	83.61 to 55.39	88.29 to 57.71	82.52 to 55.08	-
Within-group *P*-value	0.61	0.002	0.88	< 0.001	-
Total Cholesterol (mg/dL)					
Pre	192.5 ± 15.3	190.8 ± 16.1	194.2 ± 14.7	191.7 ± 15.0	0.88
Post	191.8 ± 15.2	182.0 ± 14.5	193.5 ± 14.5	180.0 ± 13.5	0.01*
Mean difference	0.7 ± 0.1	8.8 ± 1.6	0.7 ± 0.2	11.7 ± 2.5	-
95% CI	221.59 to 162.0	210.42 to 153.58	221.92 to 165.08	206.46 to 153.54	-
Within-group *P*-value	0.35	< 0.001	0.29	< 0.001	-
LDL (mg/dL)					
Pre	115.2 ± 10.5	114.8 ± 11.2	116.1 ± 10.8	115.5 ± 11.0	0.92
Post	115.0 ± 10.6	106.0 ± 10.0	116.0 ± 10.7	104.5 ± 9.5	0.01*
Mean difference	0.2 ± 0.1	8.8 ± 1.2	0.1 ± 0.1	11.0 ± 1.5	-
95% CI	135.78 to 94.22	125.6 to 86.4	136.97 to 95.03	117.24 to 91.76	-
Within-group *P*-value	0.72	< 0.001	0.81	< 0.001	-
HDL (mg/dL)					
Pre	48.5 ± 4.8	47.9 ± 5.0	49.0 ± 4.6	48.7 ± 4.9	0.85
Post	48.7 ± 4.9	52.5 ± 4.5	49.0 ± 4.8	54.0 ± 4.2	0.01*
Mean difference	-0.2 ± 0.1	-4.6 ± 0.5	0.2	-5.3 ± 0.7	-

Table 2. Continued.

Variable	Control	RT	Paullinia cupana	RT + Paullinia cupana	*P*-Value (Between-Group)
95% CI	58.30 to 39.1	61.32 to 43.68	58.41 to 39.59	62.23 to 45.77	-
Within-group *P*-value	0.48	<0.001	0.96	<0.001	-
Triglycerides (mg/dL)					
Pre	135.6±12.5	134.8±13.2	136.1±12.8	135.5±12.9	0.91
Post	135.5±12.8	125.0±11.5	136.0±12.7	122.0±11.0	0.01*
Mean difference	-0.1	9.8±1.7	-0.1	13.5±1.9	-
95% CI	160.59 to 110.41	147.54 to 102.46	160.89 to 111.11	143.56 to 100.44	-
Within-group *P*-value	0.89	<0.001	0.76	<0.001	-
CRP (mg/L)					
Pre	0.157±0.030	0.137±0.010	0.094±0.020	0.145±0.020	-
Post	0.155±0.030	0.127±0.010	0.058±0.031	0.107±0.030	-
Mean difference	0.002	0.010	0.036	0.038	-
95% CI	0.74±0.43	0.147±0.107	0.119±0.3	0.166±0.48	-
Within-group *P*-value	0.82	0.009	0.012	<0.001	-

Note. *$P<0.05$. *RT: resistance training AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; ALP: Alkaline phosphatase; LDL: Low-density lipoprotein; HDL: High-density lipoprotein; CRP: C-reactive protein; CI: Confidence interval; BMI: Body mass index; ANOVA: Analysis of variance

Table 3. Tukey Post-Hoc Comparisons for Groups With Significant Results

Variable	Comparison Group	F	*P*-Value
Weight (kg)	Control vs. RT	0.9	0.015*
	Control vs. RT + *Paullinia cupana*	0.9	0.001*
	RT vs. *Paullinia cupana*	0.9	0.03*
	Paullinia cupana vs. RT + *Paullinia cupana*	0.9	0.002*
BMI (kg/m²)	Control vs. RT	0.999	0.014*
	Control vs. RT + *Paullinia cupana*	0.3	0.001*
	RT vs. *Paullinia cupana*	0.3	0.04*
	Paullinia cupana vs. RT + *Paullinia cupana*	0.3	0.002*
AST (U/L)	Control vs. RT	11.71	0.003*
	Control vs. RT + *Paullinia cupana*	1.0	0.008*
	RT vs. Paullinia cupana	0.9	0.03*
	*Paullinia cupana*vs RT + *Paullinia cupana*	1.0	0.01*
ALT (U/L)	Control vs. RT	0.6	0.02*
	Control vs. RT + *Paullinia cupana*	0.6	0.005*
	RT vs. *Paullinia cupana*	0.5	0.04*
	Paullinia cupana vs. RT + *Paullinia cupana*	0.6	0.008*
ALP (U/L)	Control vs. RT	1.1	0.03*
	Control vs. RT + *Paullinia cupana*	1.1	0.007*
	RT vs. *Paullinia cupana*	1.0	0.04*
	Paullinia cupana vs. RT + *Paullinia cupana*	1.1	0.01*
Total cholesterol	Control vs. RT	2.9	0.012*
	Control vs. RT + *Paullinia cupana*	3.0	0.001*
	RT vs. *Paullinia cupana*	2.8	0.03*
	Paullinia cupana vs. RT + *Paullinia cupana*	3.0	0.005*
LDL (mg/dL)	Control vs. RT	2.5	0.014*
	Control vs. RT + *Paullinia cupana*	2.6	0.002*
	RT vs. *Paullinia cupana*	2.4	0.03*
	Paullinia cupana vs. RT + *Paullinia cupana*	2.6	0.004*
HDL (mg/dL)	Control vs. RT	1.2	0.01*
	Control vs. RT + *Paullinia cupana*	1.3	0.002*
	RT vs. *Paullinia cupana*	1.2	0.02*
	Paullinia cupana vs. RT + *Paullinia cupana*	1.3	0.003*
Triglycerides (mg/dL)	Control vs. RT	3.4	0.008*
	Control vs. RT + *Paullinia cupana*	3.5	0.001*
	RT vs. *Paullinia cupana*	3.3	0.02*
	*Paullinia cupana*vs. RT + *Paullinia cupana*	3.5	0.002*

Note. *$P < 0.05$ *RT: Resistance training; BMI: Body mass index (kilograms per square metre); AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; ALP: Alkaline phosphatase; LDL: Low-density lipoprotein; HDL: High-density lipoprotein.

lipid changes with RT alone, suggesting the presence of moderating factors such as training duration, diet, and baseline metabolic status (25). CRP levels significantly decreased in the groups undergoing resistance training, with or without *P. cupana*, while the control and *P. cupana* only groups displayed no significant changes (26). This demonstrates the anti-inflammatory potential of resistance exercise, likely mediated by reductions in adipose tissue and improved cytokine profiles. *P. cupana* supplementation may complement this effect through its antioxidant and anti-inflammatory properties, although the magnitude of reduction was more pronounced in the structured exercise groups (27). Mechanistically, reductions in adiposity and changes in adipokine profiles following exercise may lower systemic inflammation (28). While *P. cupana* contains polyphenols and other phytochemicals with putative anti-inflammatory properties, isolated supplementation without exercise failed to produce significant reductions in CRP in our data. Animal and mechanistic studies suggest some anti-inflammatory effects of *P. cupana*, including the modulation of adenosine metabolism and cytokine profiles.

Nonetheless, these effects may be stronger when combined with lifestyle changes or metabolic stressors (29, 30). From an immunological perspective, both resistance exercise and *P. cupana* reduce systemic inflammation by decreasing pro-inflammatory cytokines (e.g., tumor necrosis factor-α and interleukin-6) while increasing anti-inflammatory mediators, as reflected by reductions in CRP levels (31). Despite the positive outcomes in the present study, some previous research reported inconsistent or null effects. Short-term RT or isolated *P. cupana* supplementation trials have reported minimal changes in BMI, lipid profile, or CRP (32). These discrepancies may be attributed to differences in study design, including intervention duration, exercise intensity, participant characteristics, baseline metabolic status (33), and *P. cupana* dosage or bioavailability. Shorter interventions or lower exercise intensities may be insufficient to elicit measurable physiological adaptations. In addition, variability in *P. cupana* composition, caffeine content, and adherence may explain the limited effects observed in some studies (34).

Limitations of the Study

The limitations of this study included the relatively small sample size, limited intervention duration, and lack of strict control over participants' daily dietary intake. Additionally, the findings may only be generalizable to young overweight women. Therefore, future studies should consider including diverse populations, longer interventions, and different doses of *P. cupana* supplementation. Future research should also explore genetic and dietary moderators of response to exercise and supplementation composition, liver function, lipid profile, and systemic inflammation in overweight individuals.

Conclusion

In general, eight weeks of RT significantly improved body composition, liver function, lipid profile, and inflammatory status in overweight individuals. The addition of *P. cupana* supplementation further enhanced these beneficial effects, with the combined intervention producing the greatest improvements. These findings suggest that RT, particularly when combined with *P. cupana*, may be an effective strategy for improving metabolic health and reducing disease risk.

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Competing Interests

The authors declare that they have no conflict of interests related to this study.

Ethical Approval

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of IAU, VaP.C. (approval code IR.IAU.VARAMIN.REC.1404.067). Moreover, written informed consent was obtained from all participants before their inclusion in the study. This trial was also registered under the number [IRCT20171210037809N13, 2025-10-05, 86231].

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Artificial Intelligence Use Disclosure

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