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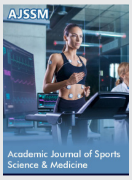

Research Article

Efficacy of Capsimax on Exercise Performance, Resting Energy Expenditure and Plasma Glucagon-Like Peptide 1: A Randomized, Double-Blind, Placebo-Controlled, Cross-Over Study

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Abstract

Purpose: Capsaicinoids exert thermogenic and modest ergogenic effects; however, evidence regarding enteric-encapsulated Capsicum extract (Capsimax) and its effects on real-time muscle performance remains limited. This study examined the acute effects of Capsimax on exercise performance, resting energy expenditure (REE), and glucagon-like peptide-1 (GLP-1) in resistance-trained men.

Methods: In this randomized, double-blind, placebo-controlled, cross-over trial, 40 healthy resistance-trained males aged 18–35 years consumed Capsimax (100 mg capsule providing 2 mg capsaicinoids) or a matched placebo once daily for 7 days, separated by a 7 ± 1-day washout period. Exercise testing was conducted 45 minutes post-dose. Primary outcomes included isometric mid-thigh pull performance and barbell back squat performance. Secondary outcomes assessed REE, upper- and lower-body resistance exercise performance, agility, reaction time, rating of perceived exertion (RPE), subjective fatigue and pain, and plasma GLP-1 levels. Adverse events were monitored during the study for safety.

Results: Thirty-nine participants completed the study as per protocol. We observed a significantly enhanced peak force and rate of force development during isometric mid-thigh pulls ($p < 0.05$) by Capsimax on Days 1 and 7 as compared to placebo. Similarly, Capsimax significantly increased peak and average power, peak force during barbell back squats, peak force and total repetitions performed during push-ups and squats and peak velocity during squats ($p < 0.05$). Further Capsimax supplementation increased REE on Days 1 and 7 along with elevated plasma GLP-1 levels on Day 7 versus placebo ($p < 0.05$). Agility and reaction time demonstrated favorable trends, while fatigue, pain, and RPE remained stable across conditions. Capsimax was well tolerated, and no serious adverse events were reported.

Conclusions: Short-term Capsimax supplementation containing enteric-encapsulated capsaicinoids produced meaningful ergogenic and metabolic benefits in resistance-trained men with improved strength, power, muscular endurance, REE, and GLP-1. Long term study with larger study population is required to further validate the effect of Capsimax on enhanced exercise performance and metabolic responses.

Keywords: Capsimax; capsaicinoids; exercise performance; GLP-1; power; resting energy expenditure

Abbreviations: 1RM: One-Repetition Maximum; AE: Adverse Event; ANOVA: Analysis of Variance; Borg CR10: Borg Category-Ratio 10 scale; ELISA: Enzyme-Linked Immunosorbent Assay; GLP-1: Glucagon-Like Peptide-1; ICMR: Indian Council of Medical Research; REE: Resting Energy Expenditure; RPE: Rating of Perceived Exertion; SAE: Serious Adverse Event; SE: Standard Error; TRPV1: Transient Receptor Potential Vanilloid 1 Channel; VAS: Visual Analogue Scale; VBT: Velocity-Based Training

Introduction

Physical activity, particularly structured exercise and athletic training, exerts substantial physiological and metabolic stress on the human body. During exercise, skeletal muscle contracts repeatedly, resulting in marked increase in energy expenditure associated with activation of multiple metabolic pathways to sustain adenosine triphosphate resynthesis [1,2]. Energy is initially supplied through phosphocreatine break-down and anaerobic glycolysis, followed by enhanced mitochondrial oxidative phosphorylation during prolonged exercise. These metabolic adjustments are accompanied by elevated oxygen consumption, increased cardiac output, and redistribution of blood flow toward active musculature. As exercise intensity rises, glycogen and glucose oxidation become the primary sources of energy, while prolonged or endurance exercise gradually shifts substrate utilization toward increased fat oxidation [3-5]. Such transitions in energy metabolism are tightly regulated by hormonal signaling, intracellular calcium flux, and activation of key enzymes that control substrate mobilization and energy production [6].

The physiological stress of exercise extends beyond energy turnover. Reactive oxygen species are generated as by-products of mitochondrial respiration and muscle contraction, creating a state of oxidative stress that can impair cell integrity, alter redox signaling, and delay recovery of muscle if not effectively managed by the body's anti-oxidant defenses. Prolonged or high-intensity training may also induce micro trauma in muscle fibers, leading to inflammation, and transient immune suppression [7]. Recovery from these effects requires coordinated replenishment of glycogen, restoration of fluid and electrolyte balance, repair of muscle tissue, and the normalization of oxidative status. Adequate nutritional intake therefore plays a fundamental role in both acute performance and long-term adaptation. Carbohydrates replenish glycogen stores, proteins provide amino acids for muscle repair and synthesis, fats contribute to energy balance and hormone regulation, and micronutrients support enzymatic reactions and antioxidant defenses [2,8,9].

In recent years, nutritional strategies aimed at optimizing recovery and adaptation have increasingly included plant-derived compounds. These bioactive substances, such as polyphenols, terpenoids, and alkaloids, contribute to antioxidant, anti-inflammatory, and vasodilatory effects that complement traditional macronutrient-based recovery [10]. By mitigating oxidative stress and inflammation, plant-based supplements may enhance muscle recovery, reduce fatigue, and improve energy utilization during sub-sequent exercise bouts [11-13]. Athletes and physically active individuals have widely adopted such supplements as natural alternatives to synthetic or pharmaceutical products, seeking to improve endurance, strength, and overall performance while minimizing potential side effects [14,15]. However, not all supplementation practices are beneficial. When nutritional requirements are unmet, whether due to inadequate dietary intake or excessive physical demand, performance declines, recovery is delayed, and injury risk increases. Conversely, dependence on artificial or pharmacological ergogenic aids, may pose health risks and contravene anti-doping regulations. Thus, evidence-based supplementation using standardized plant-derived formulations represents a promising approach to safely support metabolic balance, enhance recovery, and sustain performance. These considerations form the foundation for investigating the role of specific botanical compounds, such as capsaicinoids, in promoting endurance and muscular performance in trained individuals [16].

Capsaicinoids, the major bioactive compounds in chili peppers (capsaicin, dihydrocapsaicin and nordihydrocapsaicin), and non-pungent capsinoids have been investigated for thermogenic, lipolytic and appetite-suppressing effects, and have reported small but consistent increase in energy expenditure and fat oxidation with reduced energy intake [17-20]. Capsaicin activates transient receptor potential vanilloid 1 (TRPV1) channel in metabolically active tissues, resulting in calcium influx, sympathetic activation and increased catecholamine-mediated lipolysis. TRPV1 signaling in skeletal muscle may augment sarcoplasmic reticulum calcium release and influence contractile function, while TRPV1-mediated analgesia could reduce perceived exertion during intense exercise [20-24]. Capsimax is Capsicum annuum extract standardized to 2% capsaicinoids and enteric coated to limit gastric irritation. Through multiple human clinical studies Capsimax has been found to be safe for oral consumption and has demonstrated metabolic benefits with enhanced REE, suppressed appetite, increased serum markers of lipolysis as well as improved body composition [25-32]. Capsimax improves physical performance while reducing fatigue in experimental mice models[33]. Capsaicin or capsinoid supplementation have also reported acute effect with improved outcome on shorter time-trial times (400 m and 3000 m), increased resistance exercise volume following high-intensity intermittent exercise, reduced heart rate and lower ratings of perceived exertion in some protocols in human trials [23,24,34,35]. However, there are no studies that reported effect of Capsimax supplementation on exercise performance and real-time muscle physiology. The current study explores effect of acute and seven-day supplementation of Capsimax on exercise performance as compared to placebo, and to assess its safety and tolerability.

Methods

This was a randomized, double-blind, placebo-controlled, cross-over study designed to evaluate the acute effects of Capsimax supplementation on exercise performance in resistance-trained adults. The study was conducted at Prehab Musculoskeletal and Sports Health Clinics, Bengaluru, India, in accordance with the principles of the Declaration of Helsinki, the International Council for Harmonization E6 (R2) Good Clinical Practice Guidelines, and the National Ethical Guidelines for Biomedical and Health Research (ICMR, 2017). The study approval was obtained from the BGS Global Institute of Medical Sciences Institutional Ethics Committee, India. Voluntary written informed consent was obtained from all participants prior to enrolment after detailed explanation of the study procedures, potential risks, and need of the alternative supplementation during the study. The study was prospectively registered in Clinical Trials Registry of India - CTRI/2025/01/079598.

Study Population and Eligibility Criteria

Eligible subjects who provided informed consent underwent screening assessments to confirm eligibility based on inclusion and exclusion criteria defined in the study protocol. Details of prior and concomitant medications were recorded. The screening period was conducted from Day -3 to Day 0 (Visit 1). During this phase, demographic data, medical history, and details of prior and concomitant medications were documented. Subjects who met all inclusion criteria and did not have any of the characteristics listed in the exclusion criteria were considered eligible for participation.

Period 1: At Visit 2 (Day 1), eligible subjects underwent baseline assessments, which included fasting plasma GLP-1 concentrations measured via venous blood sampling using Enzyme-Linked Immunosorbent Assay (ELISA), REE using Breezing Pro (Breezing, USA), and isometric strength using Force Plate (KINVENT, Greece). Physical performance assessments included the barbell back squat resistance exercise protocol using VITRUVE VBT Device (VITRUVE, Spain), standard push-up test using Force Plate, and squat velocity assessment using VITRUVE VBT Device. Agility was measured by using 5-10-5 test and reaction time was measured using a reaction timer system (FITLIGHT® training system, Ontario, Canada). Subjective parameters including fatigue, pain using Visual Analog Scale (VAS), and rating of perceived exertion (RPE) were recorded using a Borg Category-Ratio 10 (CR10) scale.

Following baseline procedures, subjects were randomized in a double-blind manner using a 1:1 allocation ratio to receive either Capsimax or placebo. Forty-five minutes post-consumption of the test product, the subjects underwent assessments for REE, mid-thigh pull for the isometric strength test, barbell back squat resistance exercise protocol and standard push-up for performance, squat test for velocity-related measures, agility and reaction time, VAS for feelings of fatigue and pain, and RPE assessment immediately after exercise (POST-exercise assessments). At Visit 3 (Day 7 ± 1), the same assessment schedule as above was followed. Forty-five minutes post supplementation fasting GLP-1 levels were measured prior to exercise and post exercise assessments were performed, identical to Visit 2.

A 7±1 day washout period was implemented between Visits 3 and 4 to allow for crossover of treatments. Period 2: At Visit 4 (Day 15 ± 1), baseline assessments were conducted in accordance with the procedures of Period 1, except that GLP 1 assessment was not done. After consumption of Capsimax or placebo, all assessments were repeated after 45 minutes post-dose (POST-exercise assessments). At Visit 5 (Day 21+1), 45 minutes after supplementation, fasting GLP-1 levels were measured prior to exercise and assessments for REE, mid-thigh pull strength, barbell back squat performance, push-up test, squat velocity, agility, reaction time, VAS fatigue and pain scores, and RPE (POST-exercise) were completed. Safety assessments, including complete blood count, aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, serum creatinine, blood urea nitrogen were performed during screening visit and end of the study. Vital signs, and adverse events (AEs) were conducted at all visits.

Eligibility Criteria

Subjects who met all the following criteria were included in the study. Male subjects aged 18-35 years (both limits inclusive); subjects with a body mass index between 18.5 and 29.9 kg/m^2 at the time of screening; subjects with a minimum of one year of resistance training experience at a frequency of at least two days per week; subjects familiar with the barbell back squat exercise; subjects who were free of any physical limitations, chronic illness, or injury that could affect performance; subjects who were not under any form of medication; subjects who agreed to refrain from consuming alcohol 24 hours prior to each visit; subjects who agreed to refrain from consuming caffeine and caffeine-containing products 12 hours prior to visit days; subjects who agreed to refrain from vigorous physical activity or strenuous exercise 24 hours prior to test days; subjects willing to provide written informed consent; and subjects willing and able to understand and comply with all study requirements, consume the investigational product as instructed, attend all scheduled visits during the treatment period, comply with study-related restrictions, and complete all study procedures as required.

Subjects who met any of the following criteria were excluded from the study. Subjects who had hypersensitivity or a known history of allergy to the study product; subjects with uncontrolled hypertension (systolic blood pressure > 160 mm Hg or diastolic blood pressure > 100 mm Hg) at screening; subjects with any medical condition that could compromise participant safety or confound study results; subjects with difficulty or inability to swallow study capsules; subjects who regularly used dietary supplements containing Capsimax or other ingredients that could influence study endpoints; subjects with a history of drug and/or alcohol abuse at the time of enrolment; and subjects who had been treated with any investigational drug or device within three months prior to study entry.

The investigational product, Capsimax (OmniActive Health Technologies, India), consist of 100 mg of Capsicum annuum L. extract standardized to 2% total capsaicinoids in form of enteric coated beadlets and provided as a capsule containing not less than 2 mg total capsaicinoids. Each capsule weighed 240 mg and comprised 100 mg of Capsimax with 140 mg microcrystalline cellulose as an excipient. The placebo capsule contained 240 mg of microcrystalline cellulose and was identical in appearance to the active product to maintain blinding. Both the test and placebo products were administered orally, once daily for seven consecutive days during each supplementation period, separated by a 7±1-day washout period.

Endpoints

Primary Efficacy Endpoints

The primary efficacy endpoint was the mean change from baseline in exercise performance parameters, comparing Capsimax and placebo. These parameters included peak force (the greatest amount of force generated during a movement, typically measured in a single effort or trial), rate of force development (a measure of explosive strength, indicating how rapidly force increases from a low or resting level) and average force (refers to the average force applied by a body over a specific time interval, typically during a movement or activity) during the isometric strength test; performance during the barbell back squat resistance exercise protocol, assessed by peak power (force × velocity at the point of maximum output), average power (the total amount of work done divided by the duration of the activity, providing a basic measure of effort), peak velocity (maximum speed achieved during a movement or repetition), and peak force; and performance during the standard push-up protocol assessed by peak force and number of push-ups.

Isometric Strength Test

Isometric strength was evaluated using the isometric mid-thigh pull test, a valid and reproducible method of assessing muscle performance that requires only a single maximal effort and minimal equipment [36]. Strength was assessed as the maximal voluntary contraction exerted against a fixed, immovable resistance at a standardized joint angle using a calibrated force-measuring device (dual force plates; 1000 Hz sampling rate). The mid-thigh position was identified as the midpoint between the knee and hip joints, with participants assuming their preferred second-pull power-clean stance. The barbell height was adjusted (±2.54 cm) to ensure contact at the mid-thigh and recorded during familiarization for consistency across sessions. Participants were secured to the barbell using wrist straps and instructed to relax before the "GO!" command, then pull upward as hard and as fast as possible for 4 seconds. Each subject performed two maximal pulls separated by 3 minutes of rest, and the trial with the highest peak force was used for analysis. Peak force was defined as the highest force achieved during the test, and rate of force development was calculated from the force–time curve.

Barbell Back Squat Exercise

The barbell back squat is a widely practiced resistance exercise that targets the major lower-body muscle groups, including the quadriceps, hamstrings, and gluteus maximus. Classified as a closed kinetic chain movement, it requires maintaining foot contact with the ground throughout the motion, thereby promoting functional strength and joint stability [37]. Approximately 65-70 minutes following supplementation and after completion of isometric strength testing, participants performed a squat-specific warm-up consisting of one set at 40% and one set at 60% of one-repetition maximum (1RM) for four and two repetitions, respectively, with a 2-minute rest between sets. Subjects then completed one set of a single repetition at 70% of 1RM with maximal explosive intent, followed by a 3-minute rest period. The squat exercise protocol consisted of four sets of barbells back squats at 70% of 1RM performed to volitional fatigue, with 2 minutes of rest between sets. Failure was defined as the inability to complete a full repetition without assistance. Repetitions completed, peak power, and average power were recorded during each trial. Movement velocity and power outputs were measured using the VITRUVE velocity-based training device.

Standard Push-Up Test

Assessment of muscular strength and power is fundamental for designing effective training programs and evaluating athletic potential. The standard push-up is a widely used test of upper-body muscular endurance and has demonstrated reliability across various populations in both timed and untimed protocols. In addition to assessment purposes, the push-up is frequently incorporated into training programs to improve upper-body strength, endurance, and power [38,39]. For this study, push-up performance was assessed using a force plate to quantify force production. Participants began in a prone position on the force plate with feet shoulder-width apart and hands placed directly beneath the shoulders. To ensure consistent tempo, subjects performed the movement at a cadence of one beat per second, guided by an audible count from the research associate. Each repetition consisted of a 1-second eccentric phase (lowering), a 2-second hold at the bottom, a 1-second concentric phase (pushing upward), and a 2-second hold at the top. Following one familiarization trial, each participant performed two official 40-second trials, separated by a 2-minute rest interval to minimize fatigue. Force data were recorded throughout each trial for subsequent analysis.

Secondary Efficacy Endpoints

Secondary efficacy endpoints included the mean change from baseline in velocity-related measures during the squat test (peak velocity, peak force and number of squats), REE before exercise, agility and reaction time, VAS scores for feelings of fatigue and pain, RPE, and plasma GLP-1 concentrations.

Squat Test for Velocity Measurement

Various leg actions, such as sprint running, sprint pedalling, or vertical jumping, have been used to determine maximum power production. Accurate force and velocity measurements necessitate specialized equipment, such as linear position transducers or force plates for cycle ergometers [40]. The vertical velocity of the center of mass at take-off can be computed by integrating the vertical force trace using a force platform [41]. In this study squat test is used to determine the velocity using VITRUVE VBT Device. Also, participants performed two maximal squat trials on a force plate to assess lower-body power and velocity. Subjects stood on the force plate with hands placed on the hips, maintaining an upright chest and forward gaze. Each participant was instructed to bend into a full squat while keeping the knees aligned with the toes, then push upward through the heels to return to the starting position. Trials were repeated if proper form or range of motion was not maintained. Participants were instructed to remain still in a standing position for 2-3 seconds before and between each repetition. The number of squats completed within 30 seconds was recorded for each trial. To ensure proper technique, participants received supervised familiarization sessions two to three days prior to testing to perform squat movements correctly and without countermovement.

Agility and Reaction Time Assessment

The agility test was designed to assess the participants' ability to rapidly change direction over a short distance. A 10 m course was marked with cones at each end and a central cone serving as the start/finish point. Upon the verbal cue to begin, timing commenced as the participant moved laterally 5 m to one side to touch the end-line cone, immediately reversed direction to sprint 10 m to the opposite cone, and then changed direction a final time to sprint 5 m back to the starting point. A single timekeeper positioned at the start/finish cone recorded the trial duration. Each participant completed two trials separated by a 3-minute recovery period, and the average time of both trials was used for analysis [42,43].

Reaction time, defined as the interval between a sensory stimulus and the corresponding motor response, reflects the efficiency of cognitive processing and psychomotor performance. Slower RTs are often associated with diminished attention, focus, and processing speed [44]. Reaction time was assessed using a visual-cognitive reactionary test (FITLIGHT® training system, Ontario, Canada). Eight light pods were mounted on a "Vision Board" in a standardized configuration, with each pod positioned within arm's reach of the participant. Pod placement and subject positioning were replicated across all assessments to ensure consistency. During each 60-second trial, one light randomly illuminated at a time, and participants were instructed to strike as many lights as possible within the allotted time. The reaction time for each successful hit was recorded, and the mean reaction time was calculated for each trial. Participants completed two trials per assessment with a 30-second rest period between trials, and the faster of the two trials was used for analysis.

Resting Energy Expenditure (REE)

REE represents the largest component of total daily energy expenditure, accounting for approximately 60-70% of total caloric utilization. It reflects the metabolic activity of body cell mass and serves as an important indicator of physiological status in both healthy and clinical populations. In research settings, REE is conventionally measured using indirect calorimetry via metabolic carts, which determine respiratory gas exchange [26,45]. REE was measured using Breezing Pro™ device which provides measurements of exhalation rate, oxygen uptake and carbon dioxide production.

Visual Analog Scale for Fatigue and Pain

Subjective perceptions of fatigue [46] and pain [47] were assessed using separate 10-cm VAS, each anchored by the descriptors "low" and "high," representing the lowest and highest perceived intensities, respectively. Participants were instructed to indicate their perceived levels of fatigue and pain at each time point by marking along the corresponding line, where a greater measured value denoted a higher perceived intensity. VAS assessments were administered immediately before (PRE) and after (POST) exercise REE measurement.

Rating of Perceived Exertion (RPE)

RPE is a widely accepted and reliable method for monitoring and prescribing exercise intensity. Developed by Gunnar Borg, the Borg CR10 Scale enables individuals to subjectively rate their level of effort during physical activity or exercise testing. As recommended by the American College of Sports Medicine (2010), the RPE provides a practical measure of perceived exertion that closely corresponds with physiological markers of exercise intensity [48]. In this study, RPE was recorded immediately following the resistance exercise protocol using the Borg CR10 Scale. Participants were also asked to report any adverse effects following all assessments.

Biomarker - GLP-1 Analysis

Enteroendocrine L cells present in the lining of gastrointestinal tract release key hormones including GLP-1 in response to food intake. GLP1 plays a key physiological role in glucose homeostasis by enhancing insulin secretion, delaying gastric emptying, and reducing appetite and food intake. Experimental evidence suggests a link between exercise and GLP-1 secretion [49]. In this study, GLP-1 concentrations were quantified from venous blood samples using ELISA methods. Safety assessments included monitoring of AEs, measurement of vital signs, and descriptive analysis of clinical safety parameters.

Statistical Analysis

A sample size of 40 subjects was sufficient to detect a clinically important difference between groups with 80% power and a 5% level of significance. All data were analyzed using R statistical software (version 4.4.3). Efficacy evaluations were performed using an analysis of variance (ANOVA) model, including treatment, test, and test-by-treatment as fixed effects. The test-by-treatment term represented the interaction between test and treatment and was evaluated using Type III Tests of Fixed Effects to detect statistically significant differences at $\alpha = 0.05$. Bonferroni correction was applied for multiple comparisons of primary and secondary efficacy endpoints. A two-sided 90% confidence interval for the ratio of means was constructed using ANOVA when assumptions of normality and homogeneity of variances were satisfied. Categorical variables were analyzed using chi-square or Fisher's exact tests as appropriate. Analysis of GLP-1 levels and change from baseline was summarized by treatment group and visit, with group-wise comparisons performed using paired t-tests at a 5% level of significance.

Safety analyses were performed on the safety population, with continuous variables summarized by descriptive statistics [n, mean, standard error (SE), standard deviation, median, minimum, and maximum] and categorical variables summarized by frequency and percentage. Differences between treatment groups were evaluated using Pearson's chi-square or Fisher's exact test as appropriate. Results are expressed as mean ± SE of the mean unless otherwise stated.

Results

Subject Disposition

A total of forty male participants were randomized in this double-blind, placebo-controlled, cross-over study. Of these, thirty-nine subjects completed the study in full compliance with the protocol, while one participant discontinued prior to completion (Figure 1). Therefore, data from thirty-nine participants were included in the per-protocol efficacy evaluation, and all forty were considered in the safety population.

Citation: Arun Kumar Rawal, Harshith Chandra Shekhar, Lincy Joshua, and Jestin Thomas*. Efficacy of Capsimax on Exercise Performance, Resting Energy Expenditure and Plasma Glucagon-Like Peptide 1: A Randomized, Double-Blind, Placebo-Controlled, Cross-Over Study. Aca J Spo Sci & Med. 3(1): 2026. AJSSM.MS.ID.000559. **DOI:** 10.33552/AJSSM.2026.02.000559

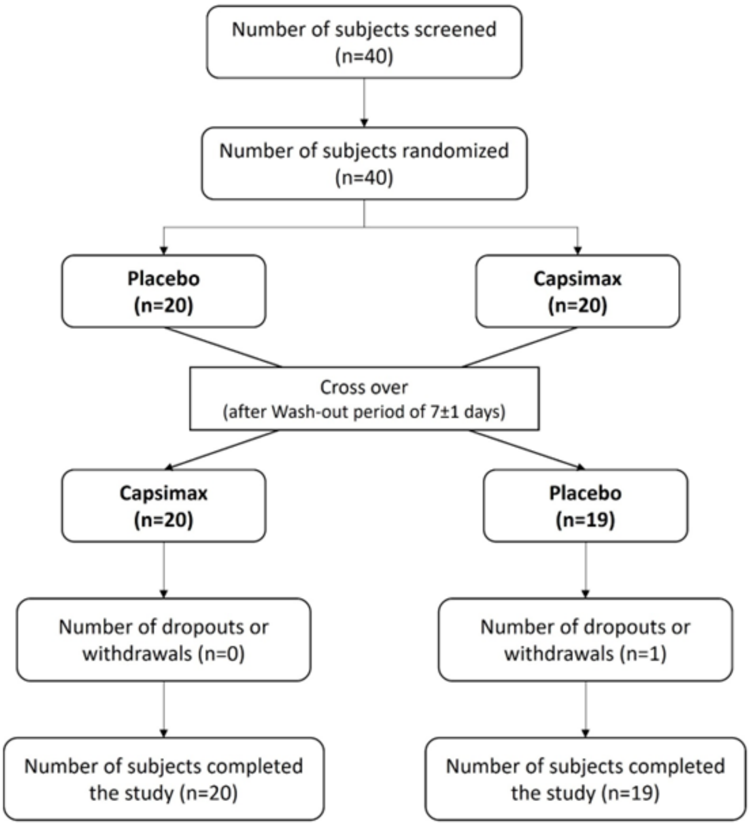

Figure 1: CONSORT flow diagram of the randomized, double-blind, placebo-controlled, cross-over study investigating the effects of Capsimax on exercise performance.

Baseline Demographic Characteristics

The study was conducted exclusively in healthy, resistance-trained male participants of Indian origin. The mean (± SE) age of participants was 24.05±0.82 years, with a mean height of 173.25±0.91 cm, a mean body weight of 70.32±1.89 kg, and a mean body mass index of 23.33±0.49 kg/m^2.

Efficacy Evaluations

A summary of efficacy endpoints comparing the placebo and Capsimax groups, along with the corresponding ANOVA outcomes, is presented in Figures 2&3, and Tables 1&2. The graphs in Figures 2&3 display mean values of the study endpoints across visits and sets, where applicable.

Table 1: Summary of primary endpoints (isometric mid-thigh pull, barbell back squat, and push-up tests) by treatment, visit, and set; ANOVA and Bonferroni post-hoc comparisons. (a) Isometric mid-thigh pull -Peak Force (Newtons); (b) Isometric mid-thigh pull - Rate of force development (Newtons/sec); (c) Isometric mid-thigh pull - Average Force (Newtons); (d) Barbell Back Squat - Peak Power (Watts); (e) Barbell Back Squat - Average Power (Watts); (f) Barbell Back Squat - Peak Velocity (meters/sec); (g) Barbell Back Squat - Peak Force (Newtons); (h) Push-up - Peak Force (Newtons); (i) Push-up - Number of Push-ups (units).

Set	Timepoint/ Difference	Placebo (N=39) Mean ± SE	Capsimax (N=39) Mean ± SE	Treatment effect at each time point (ANOVA p-value)	Capsimax vs Placebo (Bonferroni p-value)
a. Isometric mid-thigh pull – Peak Force (Newtons)					
Set 1	Visit 1	880.36 ± 32.98	846.53 ± 27.49	0.4330	-
	Visit 2	879.15 ± 34.72	912.04 ± 26.61	0.4540	-
	Visit 3	889.61 ± 34.23	953.71 ± 37.10	0.2080	-
	V2-V1	-1.21 ± 18.61	65.51 ± 20.66	0.0190*	0.0188*
	V3-V1	9.25 ± 25.85	107.18 ± 35.69	0.0290*	0.0293*
	V3-V2	10.46 ± 27.72	41.67 ± 30.32	0.4500	0.4500
Set 2	Visit 1	899.51 ± 32.61	896.89 ± 31.78	0.9540	-
	Visit 2	900.80 ± 37.22	921.13 ± 26.8	0.6590	-
	Visit 3	900.92 ± 33.55	972.36 ± 31.8	0.1260	-
	V2-V1	1.29 ± 24.65	24.24 ± 21.25	0.4830	0.4830
	V3-V1	1.41 ± 29.78	75.47 ± 23.59	0.0550#	0.0549#
	V3-V2	0.12 ± 33.65	51.23 ± 24.84	0.2260	0.2260
b. Isometric mid-thigh pull – Rate of force development (Newtons/sec)					

Set 1	Visit 1	6303.31 ± 367.37	6416.56 ± 333.37	0.8200	-
	Visit 2	6132.52 ± 345.54	7059.88 ± 352.33	0.0640#	-
	Visit 3	6403.98 ± 389.37	7524.67 ± 388.88	0.0450*	-
	V2-V1	-170.78 ± 253.61	643.32 ± 236.22	0.0210*	0.0214*
	V3-V1	100.67 ± 299.75	1108.11 ± 289.98	0.0180*	0.0181*
	V3-V2	271.45 ± 320.09	464.79 ± 360.28	0.6890	0.6890
Set 2	Visit 1	6623.83 ± 378.69	6199.66 ± 435.27	0.4640	-
	Visit 2	6467.36 ± 365.14	6816.36 ± 421.85	0.5330	-
	Visit 3	6761.51 ± 394.76	7238.39 ± 393.72	0.3950	-
	V2-V1	-156.48 ± 226.06	616.71± 266.84	0.0300*	0.0301*
	V3-V1	137.68 ± 323.36	1038.74 ± 241.37	0.0280*	0.0285*
	V3-V2	294.16 ± 348.83	422.03 ± 248.66	0.7660	0.7660
c. Isometric mid-thigh pull – Average Force (Newtons)					
Set 1	Visit 1	4002.91 ± 489.95	4461.32 ± 469.35	0.5010	-
	Visit 2	4001.79 ± 467.80	4676.42 ± 471.25	0.3130	-
	Visit 3	4075.90 ± 462.80	4898.36 ± 497.11	0.2300	-
	V2-V1	-1.12 ± 97.90	215.11 ± 137.55	0.2040	0.2040
	V3-V1	72.99 ± 155.77	437.05 ± 248.50	0.2180	0.2180
	V3-V2	74.11 ± 152.67	221.94 ± 264.73	0.6300	0.6300
Set 2	Visit 1	4382.72 ± 501.55	5328.68 ± 511.71	0.1910	-
	Visit 2	4372.17 ± 481.19	5456.76 ± 523.70	0.1310	-
	Visit 3	4452.79 ± 482.73	5720.10 ± 542.09	0.0850#	-
	V2-V1	-10.55 ± 129.12	128.08 ± 115.36	0.4260	0.4260
	V3-V1	70.07 ± 122.49	391.42 ± 144.46	0.0940#	0.0938#
	V3-V2	80.62 ± 128.37	263.35 ± 132.12	0.3240	0.3240
d. Barbell Back Squat - Peak power (Watts)					
Set 1	Visit 1	699.17 ± 31.04	649.65 ± 28.33	0.2420	-
	Visit 2	678.27 ± 29.94	703.56 ± 35.54	0.5880	-
	Visit 3	698.58 ± 27.00	797.77 ± 32.07	0.0210*	-
	V2-V1	-20.91 ± 21.41	53.92 ± 24.08	0.0230*	0.0229*
	V3-V1	-0.59 ± 21.48	148.13 ± 27.82	0.0001*	0.0001*
	V3-V2	20.32 ± 27.95	94.21 ± 22.02	0.0410*	0.0412*
Set 2	Visit 1	678.20 ± 30.12	663.66 ± 29.79	0.7320	-
	Visit 2	642.35 ± 25.37	711.61 ± 35.50	0.1170	-
	Visit 3	693.14 ± 29.94	777.38 ± 33.38	0.0640#	-
	V2-V1	-35.85 ± 19.33	47.95 ± 23.25	0.0070*	0.0070*
	V3-V1	14.95 ± 18.42	113.73 ± 21.74	0.0009*	0.0009*
	V3-V2	50.80 ± 25.46	65.78 ± 22.37	0.6600	0.6600
Set 3	Visit 1	704.78 ± 30.27	667.04 ± 29.84	0.3770	-
	Visit 2	660.14 ± 29.11	685.89 ± 32.76	0.5590	-
	Visit 3	714.76 ± 33.22	733.01 ± 29.33	0.6820	-
	V2-V1	-44.64 ± 18.36	18.85 ± 16.56	0.0120*	0.0122*
	V3-V1	9.98 ± 22.75	65.97 ± 14.28	0.0400*	0.0404*
	V3-V2	54.62 ± 28.51	47.12 ± 19.20	0.8280	0.8280
Set 4	Visit 1	678.99 ± 28.89	678.10 ± 28.90	0.9830	-
	Visit 2	661.99 ± 29.75	681.35 ± 33.97	0.6690	-
	Visit 3	709.54 ± 31.55	717.68 ± 30.01	0.8520	-
	V2-V1	-17.00 ± 19.61	3.26 ± 16.81	0.4350	0.4350
	V3-V1	30.55 ± 20.70	39.58 ± 14.27	0.7210	0.7210

	V3-V2	47.55 ± 29.54	36.32 ± 16.96	0.7430	0.7430
e. Barbell Back Squat - Average power (Watts)					
Set 1	Visit 1	297.33 ± 10.77	298.09 ± 11.27	0.9610	-
	Visit 2	292.26 ± 10.53	334.65 ± 18.48	0.0500#	-
	Visit 3	315.65 ± 20.31	374.88 ± 20.81	0.0450*	-
	V2-V1	-5.07 ± 6.08	36.56 ± 15.65	0.0150*	0.0154*
	V3-V1	18.32 ± 18.24	76.80 ± 14.94	0.0150*	0.0154*
	V3-V2	23.39 ± 19.37	40.23 ± 17.45	0.5200	0.5200
Set 2	Visit 1	287.65 ± 10.59	288.07 ± 9.98	0.9770	-
	Visit 2	279.49 ± 10.21	309.93 ± 13.13	0.0710#	-
	Visit 3	297.38 ± 10.31	333.66 ± 14.02	0.0400*	-
	V2-V1	-8.17 ± 6.07	21.86 ± 8.43	0.0050*	0.0050*
	V3-V1	9.72 ± 5.78	45.59 ± 9.89	0.0020*	0.0025*
	V3-V2	17.89 ± 7.91	23.73 ± 7.81	0.6010	0.6010
Set 3	Visit 1	296.77 ± 10.69	286.44 ± 10.43	0.4910	-
	Visit 2	284.22 ± 9.92	298.79 ± 11.79	0.3470	-
	Visit 3	299.38 ± 11.01	316.36 ± 12.19	0.3050	-
	V2-V1	-12.55 ± 4.64	12.35 ± 5.51	0.0009*	0.0009*
	V3-V1	2.61 ± 6.64	29.91 ± 7.91	0.0100*	0.0099*
	V3-V2	15.17 ± 8.09	17.57 ± 8.52	0.8390	0.8390
Set 4	Visit 1	289.58 ± 10.69	284.08 ± 10.36	0.7130	-
	Visit 2	278.52 ± 9.49	285.55 ± 11.89	0.6450	-
	Visit 3	296.62 ± 11.14	294.45 ± 9.87	0.8840	-
	V2-V1	-11.06 ± 5.43	1.47 ± 5.53	0.1100	0.1100
	V3-V1	7.04 ± 6.93	10.37 ± 8.62	0.7640	0.7640
	V3-V2	18.10 ± 9.11	8.90 ± 10.24	0.5040	0.5040
f. Barbell Back Squat - Peak velocity (meters/sec)					
Set 1	Visit 1	0.99 ± 0.02	0.99 ± 0.02	0.8960	-
	Visit 2	0.98 ± 0.02	1.01 ± 0.04	0.5240	-
	Visit 3	1.01 ± 0.02	1.04 ± 0.02	0.3100	-
	V2-V1	-0.01 ± 0.02	0.02 ± 0.04	0.4590	0.4590
	V3-V1	0.02 ± 0.02	0.06 ± 0.02	0.2430	0.2430
	V3-V2	0.03 ± 0.02	0.04 ± 0.03	0.9380	0.9380
Set 2	Visit 1	0.94 ± 0.02	0.94 ± 0.02	0.9550	-
	Visit 2	0.96 ± 0.02	0.96 ± 0.03	0.9460	-
	Visit 3	1.00 ± 0.02	1.02 ± 0.02	0.5970	-
	V2-V1	0.02 ± 0.02	0.02 ± 0.02	0.9860	0.9860
	V3-V1	0.05 ± 0.02	0.07 ± 0.02	0.5580	0.5580
	V3-V2	0.04 ± 0.02	0.06 ± 0.02	0.5110	0.5110
Set 3	Visit 1	0.98 ± 0.02	0.95 ± 0.02	0.3830	-
	Visit 2	0.94 ± 0.02	0.95 ± 0.02	0.6250	-
	Visit 3	1.00 ± 0.02	1.00 ± 0.02	0.8740	-
	V2-V1	-0.04 ± 0.02	0.00 ± 0.02	0.0600#	0.0599#
	V3-V1	0.03 ± 0.02	0.05 ± 0.02	0.3920	0.3920
	V3-V2	0.06 ± 0.02	0.04 ± 0.02	0.4860	0.4860
Set 4	Visit 1	0.96 ± 0.02	0.95 ± 0.02	0.8140	-
	Visit 2	0.94 ± 0.02	0.96 ± 0.02	0.5360	-
	Visit 3	0.99 ± 0.02	1.01 ± 0.02	0.4490	-
	V2-V1	-0.02 ± 0.02	0.01 ± 0.02	0.2500	0.2500

	V3-V1	0.03 ± 0.02	0.06 ± 0.02	0.2060	0.2060
	V3-V2	0.05 ± 0.02	0.05 ± 0.02	0.9700	0.9700
g. Barbell Back Squat - Peak force (Newtons)					
Set 1	Visit 1	723.76 ± 23.55	730.24 ± 26.32	0.8550	-
	Visit 2	712.91 ± 21.76	742.97 ± 28.42	0.4040	-
	Visit 3	717.70 ± 20.78	769.81 ± 24.33	0.1080	-
	V2-V1	-10.85 ± 10.43	12.73 ± 9.78	0.1030	0.1030
	V3-V1	-6.06 ± 14.62	39.58 ± 10.75	0.0140*	0.0140*
	V3-V2	4.79 ± 15.67	26.84 ± 13.15	0.2850	0.2850
Set 2	Visit 1	715.28 ± 24.25	720.48 ± 23.12	0.8770	-
	Visit 2	699.92 ± 23.23	731.14 ± 22.99	0.3420	-
	Visit 3	718.57 ± 22.03	757.02 ± 24.68	0.2490	-
	V2-V1	-15.36 ± 8.66	10.66 ± 10.54	0.0600#	0.0601#
	V3-V1	3.29 ± 9.58	36.54 ± 11.98	0.0330*	0.0333*
	V3-V2	18.65 ± 11.98	25.87 ± 13.10	0.6850	0.6850
Set 3	Visit 1	740.92 ± 25.75	722.59 ± 22.21	0.5910	-
	Visit 2	722.61 ± 22.43	732.40 ± 23.98	0.7660	-
	Visit 3	743.89 ± 24.34	757.93 ± 24.34	0.6850	-
	V2-V1	-18.32 ± 13.62	9.81 ± 8.31	0.0820#	0.0819#
	V3-V1	2.97 ± 9.58	35.34 ± 11.54	0.0340*	0.0341*
	V3-V2	21.28 ± 15.88	25.53 ± 12.23	0.8330	0.8330
Set 4	Visit 1	732.09 ± 25.52	724.26 ± 22.74	0.8190	-
	Visit 2	724.24 ± 24.22	731.19 ± 25.34	0.8430	-
	Visit 3	734.85 ± 23.81	753.73 ± 23.93	0.5780	-
	V2-V1	-7.85 ± 9.03	6.93 ± 6.91	0.1980	0.1980
	V3-V1	2.75 ± 7.56	29.46 ± 7.29	0.0130*	0.0130*
	V3-V2	10.60 ± 12.72	22.53 ± 8.74	0.4420	0.4420
h. Push-up - Peak force (Newtons)					
Set 1	Visit 1	660.50 ± 25.07	652.15 ± 23.08	0.8070	-
	Visit 2	662.13 ± 26.55	681.27 ± 23.21	0.5890	-
	Visit 3	665.02 ± 28.70	689.82 ± 23.04	0.5020	-
	V2-V1	1.62 ± 8.65	29.12 ± 9.24	0.0330*	0.0330*
	V3-V1	4.52 ± 10.75	37.67 ± 8.52	0.0180*	0.0181*
	V3-V2	2.90 ± 11.40	8.55 ± 11.97	0.7330	0.7330
Set 2	Visit 1	631.82 ± 22.70	647.89 ± 23.92	0.6280	-
	Visit 2	628.30 ± 23.91	662.92 ± 24.16	0.3120	-
	Visit 3	631.18 ± 22.33	675.24 ± 26.24	0.2050	-
	V2-V1	-3.53 ± 6.58	15.03 ± 8.93	0.0990#	0.0986#
	V3-V1	-0.65 ± 6.99	27.35 ± 10.83	0.0330*	0.0330*
	V3-V2	2.88 ± 9.39	12.31 ± 12.98	0.5580	0.5580
i. Push-up - Number of push-ups (units)					
Set 1	Visit 1	27.08 ± 1.67	25.36 ± 1.88	0.4960	-
	Visit 2	26.51 ± 1.85	26.67 ± 1.86	0.9530	-
	Visit 3	27.08 ± 1.63	29.36 ± 1.95	0.3720	-
	V2-V1	-0.56 ± 0.99	1.31 ± 0.64	0.1170	0.1170
	V3-V1	0.00 ± 1.10	4.00 ± 0.86	0.0050*	0.0053*
	V3-V2	0.56 ± 1.26	2.69 ± 0.80	0.1580	0.1580
Set 2	Visit 1	21.85 ± 1.34	23.54 ± 1.68	0.4330	-
	Visit 2	22.00 ± 1.20	24.00 ± 1.84	0.3650	-

	Visit 3	22.62 ± 1.28	26.74 ± 2.00	0.0860#	-
	V2-V1	0.15 ± 0.88	0.46 ± 0.95	0.8130	0.8130
	V3-V1	0.77 ± 0.96	3.21 ± 1.04	0.0900#	0.0895#
	V3-V2	0.62 ± 0.79	2.74 ± 0.83	0.0670#	0.0668#

V: Visit. Visit 1: Pre (Day 1 & 15, Sets 1–4); Visit 2: Post (Day 1 & 15, Sets 1–4); Visit 3: Post (Day 7 & 21, Sets 1–4). N.: Number of subjects; SE: Standard error; *p < 0.05; # p > 0.05 and < 0.1 (trend over placebo)

Table 2: Summary of secondary endpoints (squat test, agility, reaction time, resting energy expenditure, visual analogue scale, rating of perceived exertion, and glucagon-like peptide-1) by treatment, visit, and set; ANOVA, Bonferroni, and t-test comparisons. (a) Squat test – Peak force (Newtons); (b) Squat test – Peak velocity (meters/sec); (c) Squat test – Number of squats (units); (d) Agility time (sec); (e) Reaction time – Number of taps (units); (f) Reaction time – Average duration (sec); (g) Resting energy expenditure (Kcal/day); (h) Visual analogue scale – Fatigue (cm); (i) Visual analogue scale – Pain (cm); (j) Rating of perceived exertion (units); (k) Glucagon-like pep-tide-1 (pg/mL).

Set	Timepoint/Difference	Placebo(N=39) Mean ± SE	Capsimax (N=39) Mean ± SE	Treatment effect at each time point (ANOVA p value)	Capsimax vs Placebo (Bonferroni p-value)
a. Squat test - Peak force (Newtons)					
Set 1	**Visit 1**	1250.85 ± 47.33	1194.76 ± 36.62	0.3520	-
	Visit 2	1222.91 ± 37.84	1290.75 ± 38.11	0.2100	-
	Visit 3	1226.40 ± 47.50	1313.96 ± 45.76	0.1880	-
	V2-V1	−27.93 ± 31.28	95.98 ± 24.98	0.0030*	0.0028*
	V3-V1	−24.45 ± 41.00	119.20 ± 32.11	0.0070*	0.0073*
	V3-V2	3.49 ± 35.64	23.22 ± 29.57	0.6710	0.6710
Set 2	**Visit 1**	1289.58 ± 49.30	1230.48 ± 37.87	0.3450	-
	Visit 2	1241.83 ± 40.99	1314.40 ± 44.83	0.2360	-
	Visit 3	1232.12 ± 47.49	1339.74 ± 55.06	0.1430	-
	V2-V1	−47.75 ± 28.43	83.92 ± 29.82	0.0020*	0.0020*
	V3-V1	−57.46 ± 37.49	109.25 ± 41.79	0.0040*	0.0040*
	V3-V2	−9.71 ± 35.10	25.34 ± 32.28	0.4650	0.4650
b. Squat test - Peak velocity (meters/sec)					
Set 1	**Visit 1**	1.16 ± 0.04	1.12 ± 0.04	0.4750	-
	Visit 2	1.16 ± 0.04	1.19 ± 0.04	0.6150	-
	Visit 3	1.17 ± 0.05	1.25 ± 0.05	0.2510	-
	V2-V1	−0.01 ± 0.02	0.06 ± 0.02	0.0390*	0.0387*
	V3-V1	0.01 ± 0.03	0.13 ± 0.03	0.0050*	0.0053*
	V3-V2	0.02 ± 0.03	0.06 ± 0.02	0.2710	0.2710
Set 2	**Visit 1**	1.18 ± 0.04	1.14 ± 0.04	0.5250	-
	Visit 2	1.13 ± 0.04	1.18 ± 0.04	0.4430	-
	Visit 3	1.15 ± 0.05	1.26 ± 0.04	0.0850#	-
	V2-V1	−0.05 ± 0.03	0.04 ± 0.03	0.0430*	0.0432*
	V3-V1	−0.03 ± 0.03	0.11 ± 0.03	0.0010*	0.0011*
	V3-V2	0.01 ± 0.03	0.08 ± 0.03	0.1550	0.1550
c. Squat test - Number of squats (units)					
Set 1	**Visit 1**	19.51 ± 0.75	18.85 ± 0.73	0.5250	-
	Visit 2	19.72 ± 0.81	20.39 ± 0.89	0.5800	-
	Visit 3	19.39 ± 0.77	21.31 ± 0.86	0.1000	-
	V2-V1	0.21 ± 0.62	1.54 ± 0.52	0.1040	0.1040
	V3-V1	−0.13 ± 0.72	2.46 ± 0.63	0.0080*	0.0083*
	V3-V2	−0.33 ± 0.57	0.92 ± 0.57	0.1250	0.1250
Set 2	**Visit 1**	20.13 ± 0.75	19.26 ± 0.78	0.4230	-
	Visit 2	20.31 ± 0.93	20.21 ± 0.80	0.9330	-
	Visit 3	20.28 ± 0.79	21.46 ± 0.74	0.2780	-
	V2-V1	0.18 ± 0.78	0.95 ± 0.57	0.4260	0.4260
	V3-V1	0.15 ± 0.72	2.21 ± 0.60	0.0310*	0.0309*
	V3-V2	−0.03 ± 0.79	1.26 ± 0.45	0.1640	0.1640

d. Agility time (sec)					
Set 1	**Visit 1**	6.17 ± 0.13	6.37 ± 0.12	0.2830	-
	Visit 2	6.29 ± 0.12	6.31 ± 0.12	0.8790	-
	Visit 3	6.14 ± 0.09	6.13 ± 0.10	0.9750	-
	V2-V1	0.11 ± 0.07	−0.05 ± 0.06	0.0760#	0.0764#
	V3-V1	−0.04 ± 0.08	−0.24 ± 0.06	0.0570#	0.0565#
	V3-V2	−0.15 ± 0.05	−0.18 ± 0.05	0.6680	0.6680
Set 2	**Visit 1**	6.13 ± 0.11	6.26 ± 0.09	0.3910	-
	Visit 2	6.27 ± 0.12	6.29 ± 0.12	0.9080	-
	Visit 3	6.12 ± 0.10	6.08 ± 0.09	0.7560	-
	V2-V1	0.14 ± 0.06	0.04 ± 0.07	0.2570	0.2570
	V3-V1	−0.01 ± 0.07	−0.18 ± 0.04	0.0520#	0.0520#
	V3-V2	−0.16 ± 0.06	−0.22 ± 0.06	0.4710	0.4710
e. Reaction time - Number of taps (units)					
Set 1	**Visit 1**	60.46 ± 1.04	59.31 ± 1.32	0.4950	-
	Visit 2	59.41 ± 0.89	62.05 ± 0.96	0.0470*	-
	Visit 3	59.18 ± 1.02	61.49 ± 1.03	0.1170	-
	V2-V1	−1.05 ± 0.89	2.74 ± 0.99	0.0060*	0.0057*
	V3-V1	−1.28 ± 1.29	2.18 ± 1.33	0.0660#	0.0656#
	V3-V2	−0.23 ± 1.03	−0.56 ± 1.20	0.8340	0.8340
Set 2	**Visit 1**	61.72 ± 0.98	61.26 ± 1.29	0.7770	-
	Visit 2	59.95 ± 0.88	62.28 ± 0.89	0.0670#	-
	Visit 3	60.67 ± 0.96	62.69 ± 1.05	0.1570	-
	V2-V1	−1.77 ± 1.12	1.03 ± 1.20	0.0930#	0.0927#
	V3-V1	−1.05 ± 1.22	1.44 ± 1.76	0.2500	0.2500
	V3-V2	0.72 ± 0.85	0.41 ± 1.10	0.8250	0.8250
f. Reaction time – Average duration (sec)					
Set 1	**Visit 1**	0.64 ± 0.01	0.64 ± 0.01	0.9180	-
	Visit 2	0.63 ± 0.01	0.61 ± 0.02	0.5700	-
	Visit 3	0.64 ± 0.01	0.62 ± 0.02	0.3380	-
	V2-V1	−0.01 ± 0.01	−0.02 ± 0.01	0.5520	0.5520
	V3-V1	0.00 ± 0.01	−0.02 ± 0.02	0.2730	0.2730
	V3-V2	0.03 ± 0.01	0.00 ± 0.02	0.3110	0.3110
Set 2	**Visit 1**	0.63 ± 0.01	0.62 ± 0.01	0.8970	-
	Visit 2	0.62 ± 0.01	0.61 ± 0.01	0.5470	-
	Visit 3	0.62 ± 0.01	0.61 ± 0.01	0.6480	-
	V2-V1	−0.01 ± 0.01	−0.01 ± 0.01	0.5780	0.5780
	V3-V1	−0.01 ± 0.01	−0.02 ± 0.01	0.7250	0.7250
	V3-V2	0.00 ± 0.01	−0.01 ± 0.01	0.6160	0.6160
g. Resting energy expenditure (Kcal/day)					
-	**Visit 1**	1727.33 ± 70.37	1703.03 ± 58.22	0.7910	-
	Visit 2	1751.54 ± 68.04	1822.82 ± 57.23	0.4250	-
	Visit 3	1731.80 ± 77.13	1861.36 ± 61.16	0.1920	-
	V2-V1	24.21 ± 30.38	119.80 ± 29.85	0.0280*	0.0277*
	V3-V1	4.46 ± 51.54	158.33 ± 39.38	0.0200*	0.0202*
	V3-V2	−19.74 ± 48.90	38.54 ± 36.61	0.3430	0.3430
h. Visual analogue scale - Fatigue (cm)					
-	**Visit 1**	5.08 ± 0.14	5.10 ± 0.11	0.9430	-
	Visit 2	5.53 ± 0.18	5.43 ± 0.18	0.6840	-
	Visit 3	4.89 ± 0.08	5.14 ± 0.14	0.1220	-
	V2-V1	0.45 ± 0.13	0.33 ± 0.16	0.5640	0.9150
	V3-V1	−0.20 ± 0.16	0.04 ± 0.16	0.3090	0.6170

	V3-V2	−0.64 ± 0.18	−0.29 ± 0.22	0.2180	0.7270
i. Visual analogue scale - Pain (cm)					
-	**Visit 1**	4.97 ± 0.17	4.96 ± 0.18	0.9920	-
	Visit 2	5.27 ± 0.18	5.39 ± 0.16	0.6460	-
	Visit 3	4.87 ± 0.13	4.81 ± 0.17	0.7630	-
	V2-V1	0.31 ± 0.14	0.42 ± 0.22	0.6710	0.6710
	V3-V1	−0.09 ± 0.22	−0.15 ± 0.25	0.8540	0.8540
	V3-V2	−0.40 ± 0.21	−0.57 ± 0.24	0.5850	0.5850
j. Rating of perceived exertion (units)					
-	**Visit 1**	3.90 ± 0.20	4.18 ± 0.17	0.2890	-
	Visit 2	4.23 ± 0.27	3.90 ± 0.20	0.3260	-
	Visit 3	3.87 ± 0.17	4.21 ± 0.18	0.1910	-
	V2-V1	0.33 ± 0.31	−0.28 ± 0.21	0.1050	0.1050
	V3-V1	−0.03 ± 0.28	0.03 ± 0.28	0.8970	0.8970
	V3-V2	−0.36 ± 0.31	0.31 ± 0.26	0.1050	0.1050
k. Glucagon-like peptide-1 (pg/ml) §					
-	-	-	-	-	Independent t-test (p-value)
	V2 (Pre)	25.06 ± 0.50	25.06 ± 0.50	-	1.0000
	V3 (Post)	24.21 ± 0.44	28.20 ± 0.64	-	0.0000*
	V3 (Post) vs V2 (Pre)	−0.85 ± 0.47	3.14 ± 0.36	-	0.0000*
	Paired t-test p-value	0.0816#	0.0000*	-	-

V: Visit. Visit 1: Pre (Day 1 & 15, Sets 1 & 2); Visit 2: Post (Day 1 & 15, Sets 1 & 2); Visit 3: Post (Day 7 & 21, Sets 1 & 2). N.: Number of subjects; SE: Standard error; *p < 0.05; # p > 0.05 and < 0.1 (trend over placebo). § - Analysed using paired t-tests (within-group analysis) and independent t-tests (between-group analysis).

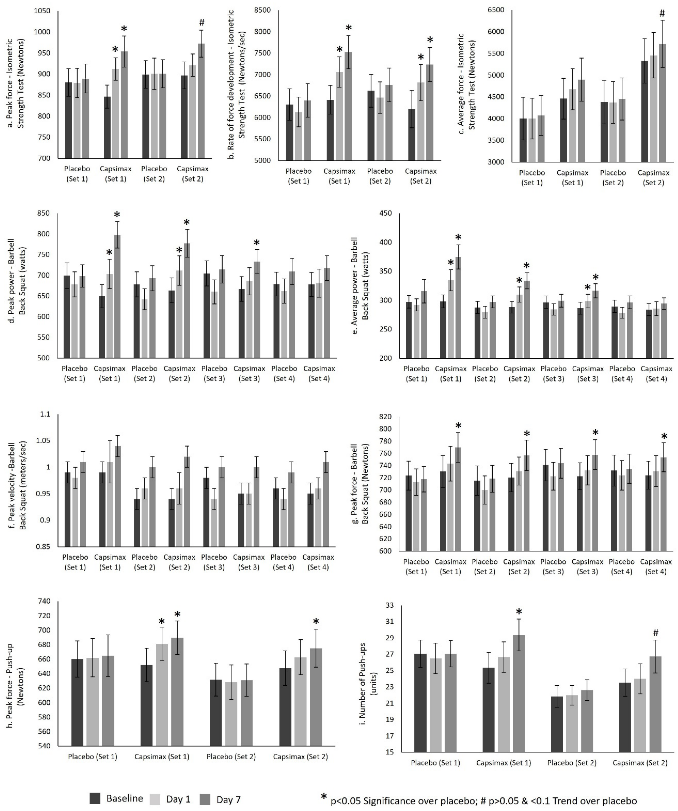

Figure 2: Summary of mean in primary endpoints comparing placebo and Capsimax groups. Isometric mid-thigh pull test assessments include peak force (a), rate of force development (b), and average force (c). Barbell back squat tests include peak power (d), average power (e), peak velocity (f), peak force (g). Push-up exercise assessments include peak force (h), and number of push-ups (i). * p<0.05 Significance over placebo; # p>0.05 & <0.1 Trend over placebo.

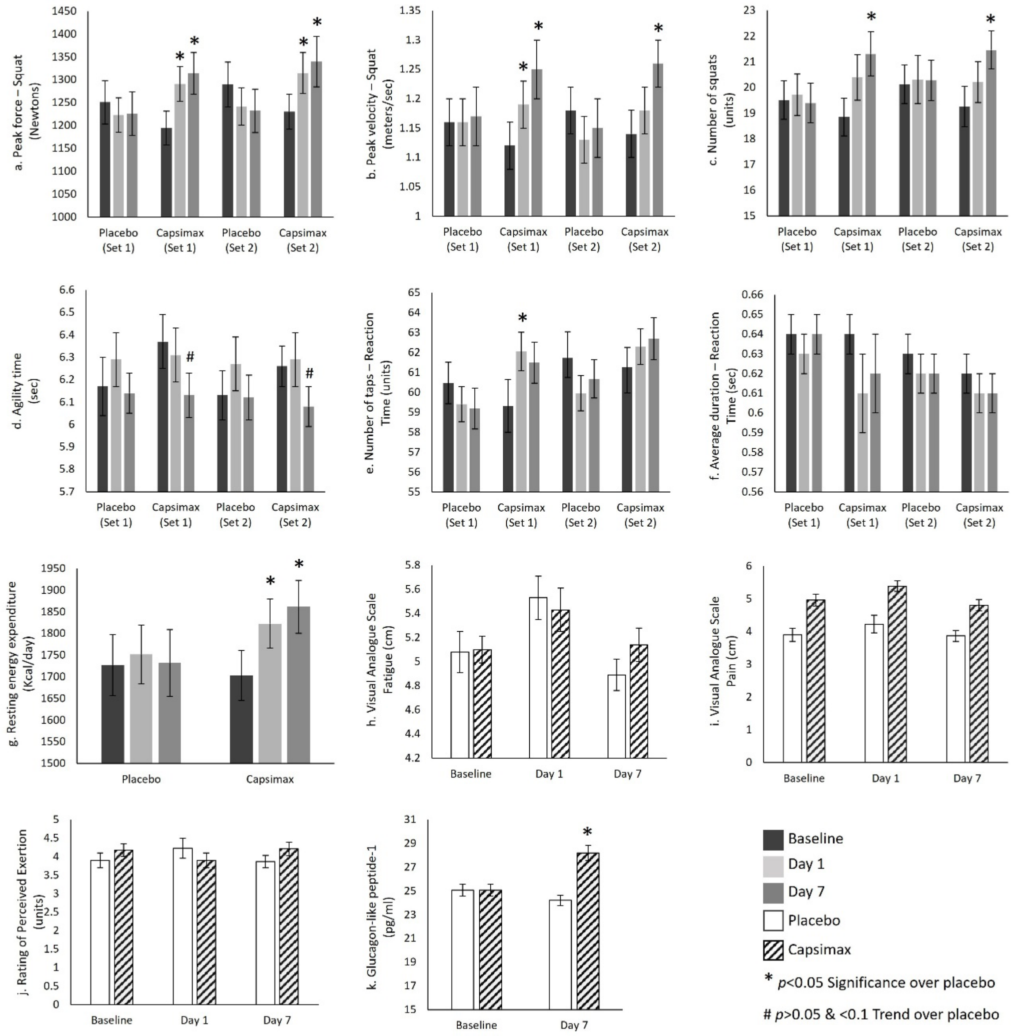

Figure 3: Summary of mean in secondary endpoints comparing placebo and Capsimax groups. Squat test results include peak force (a), peak velocity (b), and number of squats (c). Agility performance is shown as agility time (d). Reaction time assessments include number of taps (e) and average duration per tap (f). Resting energy expenditure (g); visual analogue scale measures for fatigue (h) and pain (i); rating of perceived exertion (j); and glucagon-like peptide-1 (k). * p<0.05 Significance over placebo; # p>0.05 & <0.1 Trend over placebo.

Primary Endpoints

Primary endpoints, including isometric mid-thigh pull test, barbell back squat test, and standard push-up performance, are presented in Figure 2 and Table 1.

Isometric Mid-Thigh Pull Test for Isometric Strength

Isometric mid-thigh pull test assessments included peak force, rate of force development, and average force measurements. The corresponding results are presented in Figures 2a-2c and Tables 1a-1j.

- **Peak Force**

Changes in peak force for Set 1 and 2 are illustrated in Figure 2a and Table 1a. In the isometric mid-thigh pull test, subjects who consumed Capsimax showed a significant increase in peak force during Set 1 on both Days 1 and 7 after supplementation, as well as an increasing trend (p = 0.0549) in peak force in Set 2 at Day 7 compared to those who received placebo.

- **Rate of Force Development**

Changes in rate of force development for Set 1 and 2 are illustrated in Figure 2b and Table 1b. In the isometric mid-thigh pull test, subjects who took Capsimax had a significantly higher rate of force development during Sets 1 and 2 on Days 1 and 7 after supplementation compared to those who consumed placebo.

- **Average Force**

Changes in average force development for Set 1 and 2 are illustrated in Figure 2c and Table 1c. In the isometric mid-thigh pull test, no significant differences were observed between the groups on average force during Set 1 on any visit days. Subjects who consumed Capsimax exhibited an increasing trend (p = 0.0938) in average force during Set 2 compared to those taking placebo on Day 7 after supplementation.

Barbell Back Squat Test

Barbell back squat test included peak power, average power, peak velocity, and peak force. The corresponding results are presented in Figures 2d-2h and Tables 1d-1h.

- **Peak Power**

Changes in peak force across Sets 1-4 are presented in Figure 2d and Table 1d. In the barbell back squat exercise, subjects who consumed Capsimax showed a significant increase in peak power during Sets 1 and 2 on Days 1 and 7, as well as Set 3 on Day 7, compared to those who took placebo. No significant differences were observed between the groups during Set 4 of the exercise.

- **Average Power**

Changes in average power across Sets 1-4 are presented in Figure 2e and Table 1e. In the barbell back squat exercise, subjects who consumed Capsimax exhibited a significant enhancement in average power throughout Sets 1, 2, and 3 on Days 1 and 7, in contrast to those who received placebo. No significant differences were observed between the groups during Set 4 of the exercise.

- **Peak Velocity**

Changes in peak velocity across Sets 1-4 are presented in Figure 2f and Table 1f. No significant differences were observed between the groups for peak velocity in any of the sets during the barbell back squat exercise.

- **Peak Force**

Changes in peak force across Sets 1-4 are presented in Figure 2g and Table 1g. In the barbell back squat exercise, subjects who consumed Capsimax exhibited a significant increase in peak force during Set 1, 2, 3, and 4 on Day 7 after supplementation, compared to those taking placebo.

Push-Up Test

Push-up exercise assessments included peak force and the number of push-ups. The corresponding results are presented in Figures 2h&2i and Tables 1h&1i.

- **Peak Force**

Changes in peak force for Set 1 and 2 are illustrated in Figure 2h and Table 1h. In the standard push-up exercise, subjects who consumed Capsimax exhibited a significant increase in peak force during Set 1 on Days 1 and 7 and Set 2 on Day 7 after supplementation, compared to those taking placebo.

- **Number of Push-ups**

Changes in number of push-ups for Set 1 and 2 are presented in Figure 2i and Table 1i. In the standard push-up exercise, subjects who consumed Capsimax exhibited a significant increase in number of push-ups during Set 1 on Day 7 post-dose and an increasing trend ($p = 0.0895$) on Day 7 during Set 2, compared to those taking placebo.

Secondary Endpoints

Secondary endpoints, including squat test, agility, reaction time, REE, VAS (fatigue and pain), RPE, and GLP-1, are presented in Figure 3 and Table 2.

Squat Test

The results of the squat test, including peak force, peak velocity, and number of squats, are presented in Figures 3a-3c and Tables 2a-2c.

- **Peak Force**

Changes in peak force for Set 1 and 2 are illustrated in Figure 3a and Table 2a. In the squat test, subjects who consumed Capsimax exhibited a significant increase in peak force during Sets 1 and 2 on Days 1 and 7, compared to those taking placebo.

- **Peak Velocity**

Changes in peak velocity for Set 1 and 2 are illustrated in Figure 3b and Table 2b. In the squat test, subjects who consumed Capsimax demonstrated a significant increase in peak velocity on Days 1 and 7 during Set 1, and Day 7 after supplementation in Set 2, compared to those taking placebo.

- **Number Of Squats**

Changes in number of squats for Set 1 and 2 are illustrated in Figure 3c and Table 2c. In the squat test, subjects who consumed Capsimax showed a significant increase in the number of squats during Sets 1 and 2 on Day 7 after supplementation, compared to those taking placebo.

Agility

Changes in agility time for Set 1 and 2 are illustrated in Figure 3d and Table 2d. In the 5-10-5 agility test, subjects who consumed Capsimax demonstrated a decreasing trend in agility time i.e. faster agility during Sets 1 ($p = 0.0565$) and 2 ($p = 0.0520$) on Day 7 after supplementation, compared to those taking placebo.

Reaction Time

Reaction time tests number of taps, and average duration per tap. The corresponding results are presented in Figures 3e&3f and Tables 2e&2f.

- **Number of Taps**

Changes in number of taps for Set 1 and 2 are illustrated in Figure 3e and Table 2e. In the reaction time test using FITLIGHT® training system, subjects who consumed Capsimax exhibited a significant increase in the number of taps in Set 1 on Day 1, compared to those taking placebo. No significant differences were observed between the groups on Day 7.

- **Average Duration Per Tap**

Changes in average duration per tap for Set 1 and 2 are illustrated in Figure 3f and Table 2f. In the reaction time test using FITLIGHT® training system, no significant differences were observed between the groups for average duration per tap on Days 1 and 7 in any sets.

Resting Energy Expenditure (REE)

Changes in REE are illustrated in Figure 3g and Table 2g. Subjects who consumed Capsimax demonstrated a significant increase in resting energy expenditure compared to those taking placebo, on Days 1 and 7 after supplementation.

Visual Analog Scale Fatigue

Changes in VAS fatigue are illustrated in Figure 3h and Table 2h. No significant differences were observed between the groups for VAS - Fatigue on Day 1 and 7.

Visual Analog Scale Pain

Changes in VAS pain are illustrated in Figure 3i and Table 2i. No significant differences were observed between the groups for VAS - Pain on Day 1 and 7.

Rating Of Perceived Exertion (RPE)

Changes in RPE are illustrated in Figure 3j and Table 2j. No significant differences were observed between the groups for rating of perceived exertion on Day 1 and 7.

Glucagon-Like Peptide 1 (GLP-1)

Changes in GLP-1 are illustrated in Figure 3k and Table 2k. Subjects who consumed Capsimax exhibited a significant increase in plasma GLP-1 levels compared to those taking placebo after seven days of supplementation.

Safety Evaluation

The safety of Capsimax was assessed by evaluating biochemical and hematological parameters at baseline and at the end of the supplementation period. All values remained within the normal physiological range, with no signs of clinical abnormalities. Furthermore, no significant changes were observed in hematological parameters from baseline to the end of the study. No clinically significant changes were observed in vital signs or physical examinations during the study in either the Capsimax or placebo groups. The vital parameters of all subjects remained within normal limits throughout the study period. A total of 18 AEs were reported during the study, of which 15 occurred in the Capsimax group and 3 in the placebo group. Fifteen AEs were mild in intensity, while 3 were moderate. The most commonly reported AEs included headache, fever, cold, burning sensation in the stomach, and abdominal pain. Concomitant medications were prescribed when necessary for managing these events. Five AEs in the Capsimax group were assessed as possibly related to Capsimax (Table 3). All AEs resolved completely before the end of the study. No subject experienced any serious adverse event (SAE), death, or withdrawal due to an AE or SAE. Overall, no serious or clinically significant AEs were observed, indicating that Capsimax was well tolerated during the study period.

Table 3: Summary of adverse events by treatment group and preferred term (safety population); incidence, frequency, and percentage of subjects reporting at least one adverse event.

Adverse Event (AE) Term	Placebo (N=40)	Capsimax (N=40)	Total (N=80)
	n (%)	n (%)	n (%)
Subjects Reporting at least one AE's	02 (5%)	8 (20%)	10 (12.5%)
Total AE's	3	15	18
Burning sensation in stomach	0	2	2
Headache	1	4	5
Abdominal Pain	0	2	2
Tiredness	0	1	1
Burning stool	0	1	1
Fever	1	3	4
Cold	1	2	3

Discussion

This randomized, double-blind, placebo-controlled, crossover study evaluated the acute effects of Capsimax supplementation on exercise performance and metabolic responses in resistance-trained men. The results indicated significant improvements in peak force, rate of force development, peak and average power, and peak velocity during resistance training, alongside improved muscular endurance in push-up and squat performance, as well as increased resting energy expenditure (REE). These improvements, coupled with the significant elevation of circulating GLP-1 levels, suggest that Capsimax exerts both ergogenic and metabolic benefits under acute administration. Further, Capsimax was well tolerated, throughout the study with normal biochemical and hematological observation parameters [25].

These findings of the current study are in alignment with earlier reports suggesting that capsaicinoids may enhance physical performance by exerting ergogenic effects possibly by activating transient receptor potential vanilloid 1 (TRPV1) channel in skeletal muscle [50,51]. Activation of TRPV1 induces calcium influx, which may enhance excitation-contraction coupling and force production [52]. TRPV1 stimulation also promotes sympathetic activation and catecholamine release, increasing energy availability and thermogenesis [53,54]. Together, these mechanisms may improve force and power observed following Capsimax supplementation.

Capsaicin and capsaicinoids have been shown to increase REE and fat oxidation through sympathetic stimulation and upregulation of mitochondrial activity [55,56]. The elevation in REE following Capsimax supplementation in this study is in agreement with previous clinical studies demonstrating increased energy turnover and fat oxidation after capsaicinoids ingestion [26,57,58]. In parallel, the observed rise in GLP-1 concentrations suggests a secondary metabolic pathway through which Capsimax may influence glucose regulation and increased endurance performance, as GLP-1 enhances insulin secretion [59] and energy efficiency during exercise [33].

The improvements in power and endurance performance particularly in barbell back squat and push-up protocols indicate that Capsimax may enhance both upper- and lower-body function. Prior studies report that acute ingestion of capsaicin improves total work volume and power output in resistance-trained individuals [34], suggesting that Capsimax may support acute neuromuscular activation. These findings are consistent with previous observations that report short-term performance of capsaicinoids by stimulating neural drive and metabolism rather than inducing hypertrophic changes [60]. We observed improved push-up performance in our study that further supports the hypothesis that capsaicinoids improves fatigue resistance. TRPV1-mediated calcium regulation by capsaicinoids may delay fatigue by improving sarcoplasmic reticulum calcium handling and reducing excitation-contraction uncoupling [61]. Moreover, TRPV1 activation may also reduce nociceptive signaling [62], thereby lowering perceived exertion [15] and allowing sustained effort [63] although this effect was not statistically confirmed in our results. Similarly, agility and reaction time improving trends, suggest that acute supplementation may have minimal effects on cognitive-motor performance [64].

Safety outcomes are particularly relevant when evaluating any ergogenic aid. Consistent with prior safety assessments, Capsimax was well tolerated with no SAEs or clinically significant changes to blood profile. The encapsulated beadlet design minimizes gastrointestinal irritation while maintaining bioavailability, a key advantage over unencapsulated capsaicin formulations [25]. These findings support the suitability of Capsimax as a natural, well-tolerated performance aid. The combined effects of TRPV1 activation, catecholamine-mediated lipolysis, and enhanced GLP-1 secretion suggest that Capsimax exerts multifaceted actions that can acutely enhance exercise performance. However, individual variability in responsiveness potentially influenced by TRPV1 polymorphisms, baseline fitness, or habitual spice intake may moderate its effects [65,66]. While the present findings expand evidence for the ergogenic role of capsaicinoids in humans, the selective and transient nature of the observed improvements highlights the need for longer-term studies assessing adaptation, recovery, and performance sustainability.

The findings of this study have several useful and practical implications for sports performance, exercise metabolism, and nutritional supplementation. Acute supplementation with Capsimax resulted in measurable improvements in muscular strength, power, velocity, and endurance, indicating its potential value as a pre-exercise nutritional aid for resistance-trained individuals. These benefits may be particularly relevant for athletes engaging in high-intensity, short-duration resistance or power-based activities where neuromuscular output and fatigue resistance are critical. The observed increase in REE and circulating GLP-1 levels suggests that Capsimax may also support acute metabolic enhancement, potentially contributing to improved energy utilization during exercise. This dual ergogenic–metabolic effect positions Capsimax as a supplement of interest not only for performance enhancement but also for individuals seeking improved metabolic efficiency during training.

Importantly, the favorable safety and tolerability profile observed in this study supports the short-term use of Capsimax in physically active populations. The encapsulated beadlet formulation appears to mitigate gastrointestinal discomfort commonly associated with capsaicin, improving user compliance. Collectively, these findings support the practical application of Capsimax as a safe, natural, and rapidly acting supplement for enhancing acute exercise performance. Several limitations of the present study should be acknowledged. First, the investigation focused exclusively on acute supplementation over a short duration, limiting the ability to extrapolate findings to long-term adaptations such as strength gains, hypertrophy, or metabolic re-modelling. Second, the study population with small number of subjects consisted solely of resistance-trained men, which restricts the generalizability of the results to women, untrained individuals, older adults, or clinical populations. While physiological and metabolic endpoints were assessed, molecular and cellular mechanisms underlying the observed effects-such as mitochondrial biogenesis, muscle glycogen utilization, or intracellular signaling pathways-were not evaluated. Additionally, subjective measures such as perceived exertion and cognitive-motor outcomes showed trends but did not reach statistical significance, warranting cautious interpretation.

Future studies should investigate the chronic effects of Capsimax supplementation to determine whether repeated use leads to sustained improvements in performance, recovery, and metabolic health. Longitudinal trials examining adaptations in muscle strength, hypertrophy, endurance capacity, and body composition would be particularly valuable. Research involving diverse populations, including women, older adults, and recreationally active or metabolically compromised individuals, is necessary to broaden the applicability of these findings. Incorporating molecular and mechanistic endpoints, such as markers of mitochondrial function, calcium handling, and neuromuscular signalling, would further elucidate the pathways underlying ergogenic and metabolic effects of Capsimax. Additionally, future investigations should explore dose–response relationships, timing strategies relative to exercise, and interactions with other nutritional interventions. Understanding inter-individual variability, including genetic and dietary influences on TRPV1 responsiveness, may help optimize personalized supplementation strategies.

Conclusion

This randomized, double-blind, placebo-controlled, cross-over study demonstrates that acute Capsimax supplementation enhances muscular strength, power, velocity, and endurance in resistance-trained men. These performance improvements were accompanied by increases in resting energy expenditure and circulating GLP-1 levels, indicating concurrent metabolic benefits. The observed effects are likely mediated through TRPV1 activation, leading to enhanced neuromuscular function, sympathetic stimulation, and improved energy availability during exercise. Importantly, Capsimax was well tolerated, with no adverse safety signals. Collectively, these findings support Capsimax as a safe, natural nutritional strategy for improving short-term exercise performance and metabolic responses.

Data Sharing Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval

All procedures performed in studies involving human participants were in accordance with the Good Clinical Practice guidelines, the ethical principles originated from Helsinki Declaration and in strict compliance with the "New Drugs and Clinical Trial Rules- 2019," the Ministry of Health and the Government of India, at all stages of the trial for adherence to protocol. The study activities commenced after obtaining an approval from Institutional Review Board (or Ethics Committee) of BGS Global Institute of Medical Sciences Institutional Ethics Committee, India. The study was registered with the Clinical Trials Registry of India CTRI/2025/01/079598. Informed consent was obtained from all subjects involved in the study. The EC was duly apprised of the progress and updates of the trial at regular intervals as per prescribed guidelines.

Consent To Participate

Before obtaining the patient's consent, information was given by the Investigator in language and at a level of complexity understandable to the patient in both verbal and written form. Before participation in the study, the written consent form was signed and personally dated by the patient and the Investigator. The patient received a copy of the signed and dated consent form.

Author Contributions

Conceptualization, Arun Kumar Rawal and Harshith Chandra Shekhar; methodology, Lincy Joshua and Jestin Thomas; investigation, Arun Kumar Rawal and Harshith Chandra Shekhar.; resources, Arun Kumar Rawal and Jestin Thomas; data management, Lincy Joshua and Jestin Thomas; supervision, Lincy Joshua; project administration, Lincy Joshua. All authors have read and agreed to the published version of the manuscript. Writing-original draft preparation, Arun Kumar Rawal and Harshith Chandra Shekhar; writing-review and editing, Arun Kumar Rawal, Harshith Chandra Shekhar, and Jestin Thomas.

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Disclosures

Authors report no disclosures

References

1. Coyle EF (2000) Physical activity as a metabolic stressor. Am J Clin Nutr 72(2): 512S-520S.
2. Baker JS, McCormick MC, Robergs RA (2010) Interaction among Skeletal Muscle Metabolic Energy Systems during Intense Exercise. J Nutr Metab: 905612.
3. Hargreaves M, Spriet LL (2020) Skeletal muscle energy metabolism during exercise. Nat Metab 2(9): 817-828.
4. Muscella A, Stefàno E, Lunetti P, Capobianco L, Marsigliante S (2020) The regulation of fat metabolism during aerobic exercise. Biomolecules 10(12): 1699.
5. Smith JA, Murach KA, Dyar KA, Zierath JR (2023) Exercise metabolism and adaptation in skeletal muscle. Nat Rev Mol Cell Biol 24(9): 607-632.
6. Alghannam AF, Ghaith MM, Alhussain MH (2021) Regulation of energy substrate metabolism in endurance exercise. Int J Environ Res Public Health 18(9): 4963.
7. Nancy Vargas-Mendoza, Marcelo Angeles-Valencia, Ángel Morales-González, Eduardo Osiris Madrigal-Santillán, Mauricio Morales-Martínez, et al. (2021) Oxidative stress, mitochondrial function and adaptation to exercise: new perspectives in nutrition. Life 11(11): 1269.
8. Knuiman P, Hopman MTE, Mensink M (2015) Glycogen availability and skeletal muscle adaptations with endurance and resistance exercise. Nutr Metab (Lond) 12(1): 59.
9. Adam Amawi, Walaa AlKasasbeh, Manar Jaradat, Amani Almasri, Sondos Alobaidi, et al. (2024) Athletes' nutritional demands: a narrative review of nutritional requirements. Front Nutr 10: 1331854.
10. Sorrenti V, Burò I, Consoli V, Vanella L (2023) Recent advances in health benefits of bioactive compounds from food wastes and by-products: Biochemical aspects. Int J Mol Sci 24(3): 2019.
11. Ayaz A, Zaman W, Radák Z, Gu Y (2024) Harmony in motion: unraveling the nexus of sports, plant-based nutrition, and antioxidants for peak performance. Antioxidants 13(4): 437.
12. Ayaz A, Zaman W, Radák Z, Gu Y (2024) Green strength: The role of micronutrients in plant-based diets for athletic performance enhancement. Heliyon 10(12): e32803.
13. Bojarczuk A, Dzitkowska-Zabielska M (2022) Polyphenol supplementation and antioxidant status in athletes: a narrative review. Nutrients 15(1): 158.
14. Tirla A, Islam F, Islam MR, Ioana Vicas S, Cavalu S (2022) New insight and future perspectives on nutraceuticals for improving sports performance of combat players: focus on natural supplements, importance and advantages over synthetic ones. Applied Sciences 12(17): 8611.
15. Jozo Grgic, Aamir Raoof Memon, Sitong Chen, Rodrigo Ramirez-Campillo, Gabriel Barreto, et al. (2022) Effects of capsaicin and capsiate on endurance performance: A meta-analysis. Nutrients 14(21): 4531.
16. Sukan-Karaçağıl B, Akbulut G, Açar Y, Demirkoparan M (2023) Systematic review of randomized controlled studies on capsaicinoids, capsinoids, and exercise performance. Int J Sport Nutr Exerc Metab 33(5): 291-301.
17. Whiting S, Derbyshire E, Tiwari B (2014) Could capsaicinoids help to support weight management? A systematic review and meta-analysis of energy intake data. Appetite 73: 183-188.
18. Tremblay A, Arguin H, Panahi S (2016) Capsaicinoids: a spicy solution to the management of obesity? Int J Obes (Lond) 40(8): 1198-1204.
19. Csaba Zsiborás, Róbert Mátics, Péter Hegyi, Márta Balaskó, Erika Pétervári, et al. (2018) Capsaicin and capsiate could be appropriate agents for treatment of obesity: A meta-analysis of human studies. Crit Rev Food Sci Nutr 58(9): 1419-1427.
20. Ludy MJ, Moore GE, Mattes RD (2012) The effects of capsaicin and capsiate on energy balance: critical review and meta-analyses of studies in humans. Chem Senses 37(2): 103-121
21. Barceloux DG (2009) Pepper and capsaicin (Capsicum and Piper species). Dis Mon 55(6): 380-390.
22. Panchal SK, Bliss E, Brown L (2018) Capsaicin in metabolic syndrome. Nutrients 10(5): 630.
23. de Freitas MC, Cholewa JM, de Moraes WMA, et al. (2019) Acute capsaicin supplementation improved resistance exercise performance performed after a high-intensity intermittent running in resistance-trained men. J Strength Cond Res 33(8): 2057-2065.
24. Marcelo Conrado de Freitas, Jason M Cholewa, Renan V Freire, Bruna A Carmo, Jefferson Bottan, et al. (2018) Acute capsaicin supplementation improves resistance training performance in trained men. J Strength Cond Res 32(8): 2227-2232.
25. Deshpande J, Jeyakodi S, Juturu V (2016) Tolerability of capsaicinoids from capsicum extract in a beadlet form: a pilot study. J Toxicol 2016: 2064315.
26. Deng Y, Chen F, Forzani E, Juturu V (2017) Capsaicinoids Enhance Metabolic Rate in Normal Healthy Individuals using a Novel Metabolic

Tracker Breezing Device-An Open Label Placebo Controlled Acute Study. Obes Open Access: 3(2).

27. Eric D Ryan, Travis W Beck, Trent J Herda, Abbie E Smith, Ashley A Walter, et al. (2009) Acute effects of a thermogenic nutritional supplement on energy expenditure and cardiovascular function at rest, during low-intensity exercise, and recovery from exercise. J Strength Cond Res 23(3): 807-817.

28. Bloomer RJ, Canale RE, Shastri S, Suvarnapathki S (2010) Effect of oral intake of capsaicinoid beadlets on catecholamine secretion and blood markers of lipolysis in healthy adults: a randomized, placebo controlled, double-blind, cross-over study. Lipids Health Dis 9: 72.

29. Juturu V, Deshpande J (2016) Capsaicinoids (CAPs) Decrease Appetite Measures - An Open Label Study in Free Living Individuals. FASEB J: 30.

30. Stacie L Urbina, Michael D Roberts, Wesley C Kephart, Katelyn B Villa, Emily N Santos, et al. (2017) Effects of twelve weeks of capsaicinoid supplementation on body composition, appetite, and self-reported caloric intake in overweight individuals. Appetite 113: 264-273.

31. James Rogers, Stacie L Urbina, Lem W Taylor, Colin D Wilborn, Martin Purpura, et al. (2018) Capsaicinoids supplementation decreases percent body fat and fat mass: Adjustment using covariates in a post hoc analysis. BMC Obes 5: 22.

32. Hector L Lopez, Tim N Ziegenfuss, Jennifer E Hofheins, Scott M Habowski, Shawn M Arent, et al. (2013) Eight weeks of supplementation with a multi-ingredient weight loss product enhances body composition, reduces hip and waist girth, and increases energy levels in overweight men and women. J Int Soc Sports Nutr 10(1): 22.

33. Yi-Ju Hsu, Wen-Ching Huang, Chien-Chao Chiu, Yan-Lin Liu, Wan-Chun Chiu, et al. (2016) Capsaicin Supplementation Reduces Physical Fatigue and Improves Exercise Performance in Mice. Nutrients 8(10): 648.

34. Marcelo Conrado de Freitas, Jason M Cholewa, Valéria Leme Gonçalves Panissa, Gabriela Gallucci Toloi, Hed Carlos Netto, et al. (2022) Acute Capsaicin Supplementation Improved Resistance Exercise Performance Performed After a High-Intensity Intermittent Running in Resistance-Trained Men. J Strength Cond Res 36(1): 130-134.

35. Lásaro A Costa, Marcelo C Freitas, Jason M Cholewa, Valéria L G Panissa, Fabio Y Nakamura, et al. (2020) Acute Capsaicin Analog Supplementation Improves 400 M and 3000 M Running Time-Trial Performance. Int J Exerc Sci 13(2): 755-765.

36. Juneja H, Verma SK, Khanna GL (2010) Isometric Strength and Its Relationship to Dynamic Performance: A Systematic Review. J Exerc Sci Physiother 6(2): 60-69.

37. Madeleine B Reece, Graham P Arnold, Sadiq Nasir, Weijie W Wang, Rami Abboud (2020) Barbell back squat: how do resistance bands affect muscle activation and knee kinematics? BMJ Open Sport Exerc Med 6(1): e000610.

38. Ran Wang, Jay R Hoffman, Eliahu Sadres, Sandro Bartolomei, Tyler W D Muddle, et al. (2017) Evaluating Upper-Body Strength and Power from a Single Test: The Ballistic Push-up. J Strength Cond Res 31(5): 1338-1345.

39. Contreras BMA, Schoenfeld B, Mike J, Tiryaki-Sonmez G, Vaino E (2012) The Biomechanics of the Push-up: Implications for Resistance Training Programs. Strength Cond J 34(5): 41-46.

40. Samozino P, Morin JB, Hintzy F, Belli A (2008) A simple method for measuring force, velocity and power output during squat jump. J Biomech 41(14): 2940-2945.

41. Moir GL (2008) Three different methods of calculating vertical jump height from force platform data in men and women. Measurement Phys Educ Exerc Sci 12(4): 207-218.

42. Fanchini M, Schena F, Merni F, et al. (2020) Phases of the traditional 505 test: between-session and direction reliability. J Strength Cond Res 34(12): 3486-3491.

43. Mitchell S Mologne, Trent Yamamoto, Michael Viggiano, August E Blatney, Ross J Lechner, et al. (2024) Field-based fitness measures improve via an immersive virtual reality exergaming platform: a randomized controlled trial. Front Virtual Real 5: 1290711.

44. Ananga Mohan Chandra, Suhana Ghosh, Sangita Barman, Rauf Iqbal, Nachiketa Sadhu, et al. (2010) Effect of exercise and heat-load on simple reaction time of university students. J Occup Saf Ergon 16(4): 499-510.

45. Marcella Malavolti, Angelo Pietrobelli, Manfredo Dugoni, Marco Poli, Elisa Romagnoli, et al. (2007) A new device for measuring resting energy expenditure (REE) in healthy subjects. Nutr Metab Cardiovasc Dis 17(5): 338-343.

46. Tseng BY, Gajewski BJ, Kluding PM (2010) Reliability, responsiveness, and validity of the visual analog fatigue scale to measure exertion fatigue in people with chronic stroke: a preliminary study. Stroke Res Treat 2010: 412964.

47. Domenica A Delgado, Bradley S Lambert, Nickolas Boutris, Patrick C McCulloch, Andrew B Robbins, et al. (2018) Validation of Digital Visual Analog Scale Pain Scoring with a Traditional Paper-based Visual Analog Scale in Adults. J Am Acad Orthop Surg Glob Res Rev 2(3): e088.

48. Williams N (2017) The Borg Rating of Perceived Exertion (RPE) scale. Occup Med 67(5): 404-405.

49. Luting Wu, Min Zhou, Tianyou Li, Niu Dong, Long Yi, et al. (2022) GLP-1 regulates exercise endurance and skeletal muscle remodeling via GLP-1R/AMPK pathway. Biochim Biophys Acta Mol Cell Res 1869(9): 119300.

50. Vahidi Ferdowsi P, Ahuja KD, Beckett JM, Myers S (2021) TRPV1 activation by capsaicin mediates glucose oxidation and ATP production independent of insulin signalling in mouse skeletal muscle cells. Cells 10(6): 1560.

51. Derbenev AV, Zsombok A (2016) Potential therapeutic value of TRPV1 and TRPA1 in diabetes mellitus and obesity. Semin Immunopathol 38(3): 397-406.

52. Calderón JC, Bolaños P, Caputo C (2014) The excitation-contraction coupling mechanism in skeletal muscle. Biophys Rev 6(1): 133-160.

53. Christie S, Wittert GA, Li H, Page AJ (2018) Involvement of TRPV1 channels in energy homeostasis. Frontiers in endocrinology 9: 420.

54. Jiexin Wang, Maohui Liu, Lingmiao Wen, Pengfei Xing, Jiawei Chen, et al. (2025) Role of TRPV1 in neuroendocrine regulation: a potential target against obesity? Frontiers in Immunology 16: 1598804.

55. Janssens PL, Hursel R, Martens EA, Westerterp-Plantenga MS (2013) Acute effects of capsaicin on energy expenditure and fat oxidation in negative energy balance. PloS one 8(7): e67786.

56. Inoue N, Matsunaga Y, Satoh H, Takahashi M (2007) Enhanced energy expenditure and fat oxidation in humans with high BMI scores by the ingestion of novel and non-pungent capsaicin analogues (capsinoids). Biosci Biotechnol Biochem 71(2): 380-389.

57. Yoshioka M, St-Pierre S, Suzuki M, Tremblay A (1998) Effects of red pepper added to high-fat and high-carbohydrate meals on energy metabolism and substrate utilization in Japanese women. Br J Nutr 80(6): 503-510.

58. Morde A, Rai D, Acharya M, Padigaru M (2021) Capsaicinoids Increase Resting Metabolic Rate in Healthy Individuals under Fasting Condition. J Obes Overweig 7(2): 201.

59. Smeets AJ, Westerterp-Plantenga MS (2009) The acute effects of a lunch containing capsaicin on energy and substrate utilisation, hormones, and satiety. Eur J Nutr 48(4): 229-234.

60. Jiménez-Martínez P, Ramirez-Campillo R, Flandez J, Alix-Fages C, Baz-Valle E, et al. (2023) Effects of oral capsaicinoids and capsinoids supplementation on resistance and high intensity interval training: A systematic review of randomized controlled trials: 18(2).

61. Ryo Ikegami, Hiroaki Eshima, Takuro Mashio, Tomosada Ishiguro, Daisuke Hoshino, et al. (2019) Accumulation of intramyocyte TRPV1-mediated calcium during heat stress is inhibited by concomitant muscle contractions. J Appl Physiol 126(3): 691-698.

62. Immke DC, Gavva NR (2006) The TRPV1 receptor and nociception. In: Semi Cell Dev Biol 17(5): 582-591.

63. Zhidan Luo, Liqun Ma, Zhigang Zhao, Hongbo He, Dachun Yang, et al. (2012) TRPV1 activation improves exercise endurance and energy metabolism through PGC-1α upregulation in mice. Cell res 22(3): 551-564.

64. Fioretta Silvestri, Matteo Campanella, Maurizio Bertollo, Maicon Rodrigues Albuquerque, Valerio Bonavolontà, et al. (2023) Acute effects of fitlight training on cognitive-motor processes in young basketball players. Int J Environ Res Public Health 20(1): 817.

65. Varillas-Delgado D (2025) Nutritional Intervention and Ergogenic Aids in Sport Performance and Recovery. Nutrients 17(17): 2806.

66. Guest NS, Horne J, Vanderhout SM, El-Sohemy A (2019) Sport nutrigenomics: personalized nutrition for athletic performance. Front Nutr 6: 8.

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