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ORIGINAL ARTICLE

Does creatine supplementation improve strength and power in physically active individuals on a vegan diet? a randomized, triple-blind, placebo-controlled trial

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Abstract

Purpose This study aimed to assess the impact of four weeks of creatine monohydrate supplementation on strength and power performance in physically active individuals following a vegan diet.

Methods Twenty physically active vegan adults (18–45 years) were enrolled in a triple-blind, placebo-controlled study. Participants were randomly assigned to receive either creatine monohydrate (0.1 $g \cdot kg^{-1} \cdot day^{-1}$; 5 females and 5 males) or a placebo (5 females and 5 males), while adhering to a normocaloric vegan diet. Body composition, physical performance (countermovement jump test (CMJ), sprint, repeated jumps, handgrip strength, and isometric mid-thigh pull), and renal biomarkers were assessed at baseline and after a 4-week supplementation period.

Results After 4 weeks, the creatine group showed significant increases in skeletal muscle mass (+0.3 kg), total body water (+1.4 kg), and BMI (+0.3 kg/m²), along with reduced body fat (-1.4 kg) compared to controls ($p < 0.05$). Serum creatinine and creatine levels significantly increased in the creatine group ($p < 0.001$–0.03). Performance improvements were observed in lower-body explosive performance, particularly in CMJ, as well as in maximal height and flight time during repeated jumps ($p < 0.001$–0.04), with no changes in sprint or strength tests.

Conclusion Four weeks of creatine supplementation in individuals following a vegan diet enhances muscle strength and lower-body muscular power. Longer-term studies are needed to confirm the effectiveness and safety of creatine supplementation in this population.

Trial registration NCT06483321. https//clinicaltrials.gov/study/NCT06483321.

Keywords Exercise performance · Vegan diets · Muscular power · Muscular adaptation · Renal function

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Introduction

Plant-based diets have garnered growing scientific interest due to their association with potential health benefits and reduced environmental impact (Raj et al. 2025). Among these dietary patterns, vegan diets exclude all animal-derived foods, leading to lower intakes of nutrients naturally abundant in animal products, such as creatine (Hargreaves et al. 2023). Creatine is a nitrogen-containing compound primarily found in red meat, fish, and other animal products. In the absence of these creatine-containing foods, a vegan dietary pattern relies on the endogenous synthesis of creatine from its amino acid precursors (arginine, glycine, and methionine) in the liver, kidneys, and pancreas (Gutiérrez-Hellín et al. 2024). Although endogenous creatine synthesis is sufficient to meet basic physiological needs, the total creatine pool (phosphocreatine and free creatine) in skeletal muscle tends to be lower in vegans compared to omnivores. This reduction may negatively influence muscle function and exercise performance (Burke et al. 2003a), since creatine plays an important role in energy metabolism.

Creatine supplementation has been extensively studied for its ergogenic benefits, particularly in enhancing muscular strength, power output, and high-intensity exercise capacity by increasing phosphocreatine stores in muscle tissue (Wang et al. 2024). A larger phosphocreatine and free creatine pool following supplementation increases the capacity to rapidly resynthesize ATP during short periods of high-intensity activity. Additionally, creatine supplementation combined with resistance training supports gains in muscle thickness (assessed via ultrasound) in both the upper and lower body compared to resistance training and placebo, with a greater benefit observed in younger compared to older adults (Burke et al. 2023). While the effects of creatine are well-established in omnivorous individuals, research on the impact of creatine supplementation on individuals following a vegan diet is limited. Importantly, vegans may respond differently due to lower baseline creatine stores (Kaviani et al. 2020). In theory, these individuals could experience a greater response to creatine supplementation due to differences in baseline creatine levels (Burke et al. 2003b), making supplementation particularly relevant for optimizing performance in athletes and physically active individuals with vegan diet.

Although creatine has been extensively studied for its ergogenic effects, the available evidence specifically evaluating its impact in individuals following a vegan diet remains scarce. It remains unclear whether the standard creatine dose, largely inferred from studies conducted in omnivorous populations, is similarly effective in individuals adhering to a vegan diet, particularly given their characteristically lower baseline creatine levels. Therefore, the purpose of this study was to evaluate the effects of creatine supplementation over 4 weeks on strength and power performance in physically active individuals following a vegan diet. A secondary objective was to examine biomarkers of creatine metabolism to assess the impact of supplementation on body composition and renal function.

Methods

Participants

Participants were recruited via flyers distributed on the Francisco de Vitoria University campus (Madrid) and through the dissemination of the experiment on social media during March and April 2024. The sample size was estimated with G *Power® software (3.1.9.7; Heinrich Heine University of Düsseldorf, Germany), considering the countermovement jump (CMJ) height as the primary outcome and based on effect sizes reported in previous studies evaluating the impact of creatine supplementation on this variable (Haff et al. 2000; Izquierdo et al. 2002). Due to the complexity of estimating sample size for linear mixed-effects models, a repeated-measures ANOVA (within–between interaction) approach was used as an approximation. Based on previous studies examining the effects of creatine supplementation on lower-body performance, a large effect size (Cohen's $d = 0.8$) was initially considered (Wang et al. 2018). The analysis indicated that a minimum of 16 participants was required. Considering a potential dropout rate of 20%, the final sample size was set at 20 participants ($n = 10$ per group). The inclusion criteria included both men and women aged 18 to 45 years, with a body mass index (BMI) ranging from 18.5 to 24.9, who were non-smokers, engaged in moderate-intensity physical activity 3 to 5 days per week, and had adhered to a vegan diet for a minimum of six months. The physical activity primarily consisted of habitual exercise routines including resistance training and other forms of structured or unstructured physical activity, although no standardized training program was imposed. Additionally, participants were required not to have consumed creatine monohydrate in the last six months. The exclusion criteria included pregnancy or lactation, as well as chronic diseases (cardiovascular, metabolic, or respiratory) that could interfere with the proper performance of the physical tests to be conducted. Participant eligibility was determined through an ad hoc pre-participation questionnaire and screening process. Prior to enrolment, potential participants were informed about the potential risks and any possible discomforts associated with the research protocol. Following this, they were required to provide written informed consent. The study protocol and design were approved by the Ethics Committee of the

University Francisco de Vitoria and fully complied with the principles outlined in the 1964 Helsinki Declaration and its subsequent amendments (most recent update in 2013). The study was registered on ClinicalTrials.gov (NCT06483321) and reported to the CONSORT reporting guideline for randomized clinical trials.

Trial design

This study was designed as a parallel-group, randomized, triple-blind, placebo-controlled trial. Participants were randomly assigned to either a control group (placebo supplement) or an experimental group (creatine monohydrate supplement). Block randomization was performed by an independent researcher not involved in the study, using the Research Randomized web service, based on a unique number assigned to each participant (Research Randomizer. Free Random Sampling and Random Assignment., 2025). The primary outcome was CMJ height. Secondary outcomes included body composition, sprint performance, repeated jump variables, handgrip strength, isometric mid-thigh pull, and biochemical markers of creatine metabolism. The study followed a structured timeline. Participants first completed all baseline assessments, including dietary evaluation, body composition, blood sampling, and physical performance testing. Immediately after baseline testing, participants began the supplementation protocol, which lasted for 4 weeks. During this period, dietary intake and physical activity were monitored. Upon completion of the supplementation period, participants returned to the laboratory to repeat all assessments under identical conditions and at the same time of day as baseline.

Before the onset of the study, participants visited the laboratory for an initial dietary evaluation conducted by a registered dietitian to assess dietary patterns. Participants' total daily energy expenditure was estimated using the Harris-Benedict equation, which involves calculating the basal metabolic rate and multiplying it by 1.55 to account for moderate physical activity. Based on this data, a dietitian prescribed a normocaloric diet consisting of 1.4–1.5 g/kg/day of protein, 50–55% of total calories from carbohydrates, and the remaining 15–20% from fats (Kerksick et al. 2018). Participants followed this diet for 4 weeks, and any deviations from the foods recommended by the dietitian were noted and analyzed. For this analysis, dietary intake throughout the intervention was monitored using three 24-hour dietary recalls per week (two non-consecutive weekdays and one weekend day). Participants recalled the foods consumed, along with their weights and/or household measurements. Food consumption data were processed using specific software (Dietopro, Valencia, Spain) (García et al. 2014). If a deviation from the prescribed diet affected the main dietary pattern for more than one day, the participant was excluded from the analysis.

Once the dietary standardization was completed, participants visited the laboratory, where they underwent blood and urine analyses, body composition assessment, and a battery of physical performance tests. The supplementation period then began. Participants consumed a daily dose of 0.1 $g \cdot kg^{-1} \cdot day^{-1}$ of creatine monohydrate in powder form (Creapure®; Crown Nutrition, La Rioja, Spain), while the control group received an isovolumetric placebo (Maltrodextrin; Crown Nutrition, La Rioja, Spain). Both products were indistinguishable in taste, color, texture, and appearance, ensuring the triple-blind nature of the study. A supplementation protocol without a loading phase was used, as moderate daily doses have been shown to effectively increase intramuscular creatine stores over time, while potentially improving tolerability and adherence (Antonio et al. 2021a). In addition, although a loading phase may accelerate creatine saturation, our approach was designed to reflect a practical and commonly used supplementation strategy. The supplementation was provided in black containers labelled as X and Y by the supplier. Allocation concealment was maintained until the completion of the study and the analysis of the results. Compliance was monitored through daily supplementation logs, and participants were contacted weekly to reinforce adherence. Participants were instructed to continue their regular exercise routine. No structured or supervised training program was implemented, and participants maintained their habitual training routines throughout the intervention. Physical activity levels were assessed using the International Physical Activity Questionnaire (IPAQ) during the final week of the study. Results were expressed as the median metabolic equivalent of task (MET)-minutes per week, providing a standardized measure of weekly physical activity (IPAQ 2010). Adverse events were monitored throughout the intervention via weekly follow-up and participant self-report.

Experimental protocol

Participants were instructed to refrain from strenuous physical activity for 24 h before the testing sessions. Additionally, they were required to avoid caffeine, alcohol, and any ergogenic aids for at least 48 h before assessments to minimize potential confounding effects. On the night before testing, participants were encouraged to maintain regular sleep patterns, aiming for 7–9 h of rest.

On test days, participants arrived at the laboratory, where they underwent a blood pressure measurements, blood sample collection, anthropometric assessments, and hydration status evaluation. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured with a digital

sphygmomanometer (Omron, Japan) in triplicate. Hydration was assessed through urine-specific gravity analysis, and participants were required to consume 500 mL of water 1 h before testing to ensure euhydration status (USG < 1.020). After the initial assessments, participants completed a standardized warm-up protocol, which included 5 min of light cardiovascular exercise, followed by dynamic stretching and mobility exercises targeting both the upper and lower body. This was followed by specific neuromuscular activation drills designed to optimize performance in subsequent testing.

The physical performance assessments included a CMJ, repeated jump test, sprint test, an assessment of isometric handgrip strength, and isometric mid-thigh pull. These tests were performed in a fixed sequence to ensure consistency across participants. All evaluations were performed at the same time of day, with the same environmental conditions and researcher supervision to maintain methodological consistency.

Anthropometric measurements and analytical procedure

Body mass, body fat mass, body fat percentage, body water and skeletal muscle mass were measured using a multi-frequency, tetrapolar bioelectrical impedance analysis device (Inbody Co., Ltd., Seoul, Korea) with predictive equations provided by the manufacturer. All body composition variables obtained from bioelectrical impedance analysis should be interpreted as estimates rather than direct measurements. To measure body height, participants remained standing, fully erect, with feet together, head in the Frankfort plane and arms hanging freely to the nearest millimetre (0.1 cm). The formula body mass (kg)/height (m)^2 was used to calculate body mass index (BMI). The analysis of the biomarkers was carried out by authorized personnel at a certified clinical laboratory in Madrid, Spain (Megalab S.L.), using fasting venous blood samples. The following parameters were determined: urea, creatine kinase (CK), plasma creatine, and plasma creatinine.

Physical performance test

To minimize potential learning effects, all participants completed a standardized familiarization session with all physical performance tests on the same day prior to baseline measurements, following identical procedures and instructions to those used during the testing sessions.

Sprint

Participants performed a 30 m maximal sprint test. A timing gate (Witty, Microgate, Bolzano, Italy) was positioned at the 0 and 20 m marks. The starting position was standing, 1 m behind the first timing gate. Each participant performed two attempts, separated by 2 min. A third attempt was performed if there was ≥ 10% difference in sprinting times. Participants were verbally encouraged to continue sprinting until they passed the final timing gate. The test demonstrated good reliability, with a coefficient of variation (CV) of 2.07% (Skujytė et al. 2024).

Isometric handgrip strength

Isometric handgrip strength was assessed with the shoulder and elbow positioned at 0 degrees of flexion, and the hand and forearm in a neutral position (Martín-López et al. 2022). Two maximal contraction attempts were performed for both the dominant and non-dominant hand using a calibrated dynamometer (Takei 5101, Tokyo, Japan). The highest force value from each hand was used for further analysis. The reported CV for this test is 4.1% (López-Samanes et al. 2017).

CMJ

CMJ was performed using a commercially available infrared jump system (Optojump, Microgate, Italy). Standard methodology as outlined by the manufacturer was followed (Bosco et al. 1983). Briefly, each jump began from a stationary standing position, followed by 90° of knee flexion before the jump phase. Participants were instructed to keep their hands on their waist throughout the entire CMJ. They performed two attempts, with a one-minute rest period between each trial. The highest jump height from the two attempts was recorded and used for subsequent statistical analysis. An additional measurement was performed whenever the difference between consecutive attempts exceeded 5%. The reported CV for this test is 2.7% (Glatthorn et al. 2011).

Repeated vertical jump test

Repeat power ability was calculated following 15 repeated vertical jumps (Natera et al. 2023). The protocol described in previous studies was followed (Papadakis et al. 2022). Participants adopted an upright position with their hands on their hips, and five vertical jumps were performed as familiarization prior to the actual testing. The test consisted of one series of 15 maximum continuous vertical jumps, performed as high and as fast as possible. Flight time, contact

time, and jump height were measured for each jump using an infrared jump system (Optojump, Microgate, Italy).

Isometric mid-thight pull

The isometric mid-thigh pull assessment was conducted following previous studies using the Force-Decks FD4000 Dual Force Platform (ForceDecks, London, United Kingdom) at a sampling frequency of 1000 Hz (Dos'Santos et al. 2016). Prior to the assessment, the pulling position was determined for each participant. The bar height was adjusted to ensure contact with the midpoint between the knee and hip joints. Participants were allowed to use lifting straps to prevent grip strength from limiting force production. Participants were instructed to remain relaxed and initiate the pull 6 s after receiving the verbal command. Peak force was defined as the maximal force during the 6-second pull, subtracting the participant's body weight (N). Each participant performed two attempts, and the attempt yielding the highest peak force was selected for analysis. The reported CV for this test is 3.6% (Giuliano et al. 2024).

Statistical analysis

Analyses were conducted both by intention-to-treat and per-protocol, allowing assessment of potential renal alterations (captured in intention-to-treat) as well as the real effectiveness of supplementation on physical performance (per-protocol). Given that no participants dropped out, the intention-to-treat and per-protocol analyses yielded identical results. All variables are presented as mean ± SD, given Shapiro–Wilk tests confirmed normal distribution of all data. For the strength, power performance and body composition variables, linear mixed-effects models were applied, including group (creatine vs. placebo), time (pre vs. post), and their interaction (group × time) as fixed effects, with participants included as a random effect to account for within-subject variability. For renal function variables, within-group pre–post comparisons were conducted using paired Student's t-tests. Dietary intake variables were analyzed using repeated-measures ANOVA.

The effect size was measured using partial eta squared (η^2p), which was calculated to assess the magnitude of the differences between conditions for each variable. The effect sizes were interpreted as follows: trivial = < 0.01, small = 0.01–0.06, medium = 0.06–0.14, and large = ≥ 0.14) (Cohen 1977). Additionally, Cumming estimation plots were used to visualize individual responses and effect sizes for strength and power performance outcomes, providing a complementary estimation-based interpretation of the results. Statistical significance was considered at $p \leq 0.05$. All statistical analyses were performed using R (version 4.5.2; R Foundation for Statistical Computing, Vienna, Austria) within the RStudio environment (version 2025.09.2 + 418; RStudio, Boston, MA, USA)(Lakens 2013).

Results

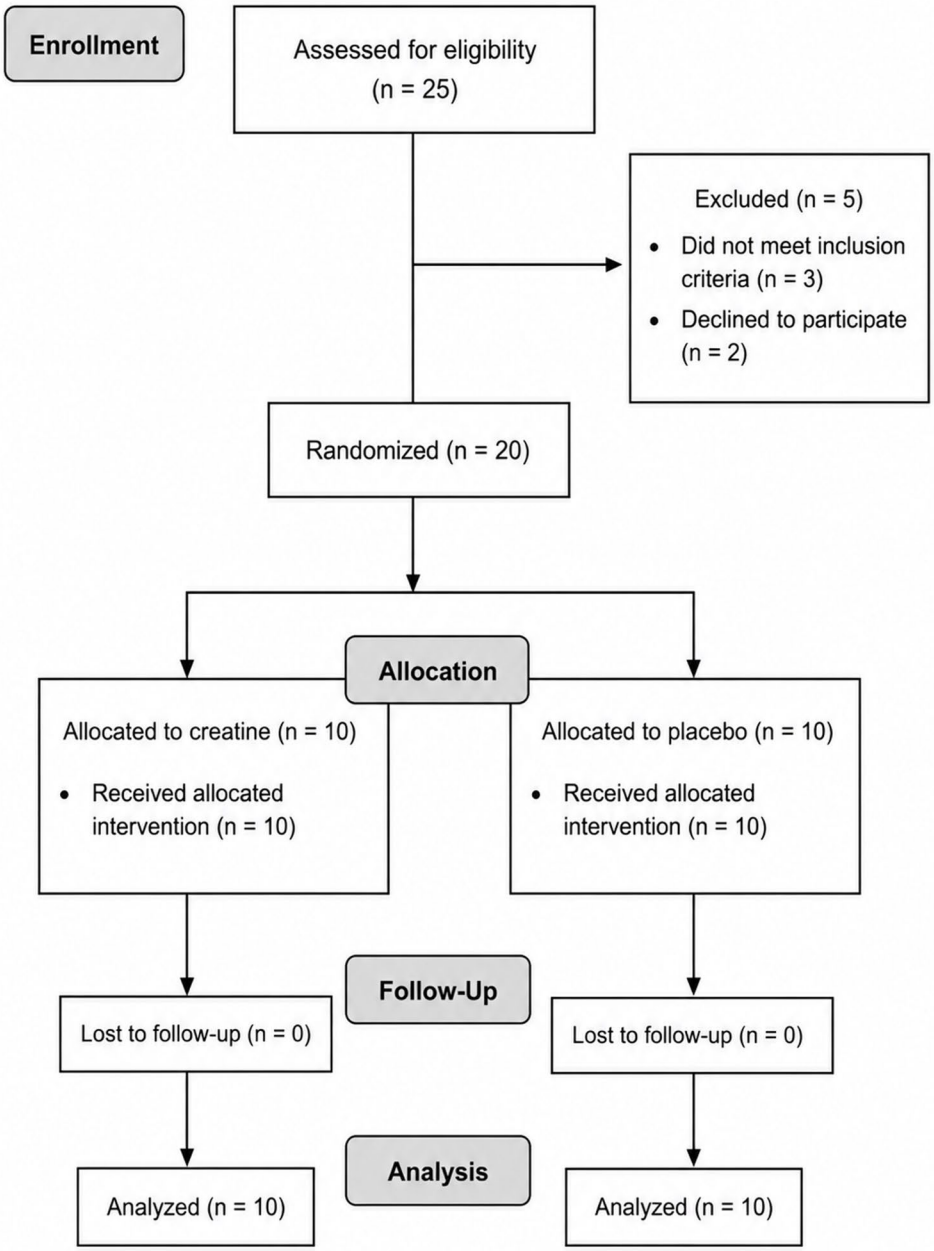
The study included a total of 20 physically active and healthy participants following a vegan diet, randomly assigned to one of two groups: 10 in the experimental group receiving creatine supplementation (5 females and 5 males) and 10 in the control group receiving a placebo (5 females and 5 males) (Fig. 1). The mean age of participants in the experimental group was 30.8 ± 9.6 years, while the control group had a mean age of 28.9 ± 5.8 years ($p > 0.05$). No significant baseline differences were observed between the creatine group and the control group in body composition, blood pressure, or hydration status ($p > 0.05$; Table 1). No significant differences were observed in any dietary or macronutrient variable between pre- and post-intervention in either the creatine supplementation or control group ($p > 0.05$; Table 2). Similarly, physical activity levels, measured as MET-minutes per week, showed no significant differences between groups (1440 MET·min/week in the creatine group vs. 1390 MET·min/week in the control group; $p > 0.05$).

Physical performance variables

Table 3 presents the results of the physical performance assessments conducted before and after the intervention in both the experimental and control groups. Significant group × time interaction effects were observed for jump-related variables. Specifically, creatine supplementation led to greater improvements in CMJ height compared to placebo (mean difference (MD): 3.29 cm; standard error (SE): 1.22; 95% confidence interval CI 0.72 to 5.85; $p = 0.015$). Similarly, significant increases were observed in repeated jump performance, including flight time (MD: 0.02 s; SE: 0.003; 95% CI 0.01 to 0.02; $p < 0.001$) and jump height (MD: 1.87 cm; SE: 0.55; 95% CI 0.67 to 3.06; $p = 0.004$). Figures 2 presents the significant differences between pre- and post-intervention in the experimental group for jump height across the 15 jumps. Notably, significantly greater flight time and jump height were observed in jumps 5–9 and 12–15 in the post-test ($p < 0.001$–0.04).

No significant differences were observed between groups for 30 m sprint performance (MD: −0.11 s; SE: 0.07; 95% CI −0.27 to 0.05; $p = 0.157$), isometric handgrip strength in the dominant (MD: 0.89 kg; SE: 0.99; 95% CI −1.18 to 2.98; $p = 0.376$) or non-dominant hand (MD: −0.83 kg; SE: 1.57; 95% CI −4.13 to 2.47; $p = 0.604$), or isometric mid-thigh pull (MD: 68.4 N; SE: 118; 95% CI −179 to 316;

Fig. 1 Flow chart



$p = 0.568$). Contact time during repeated jumps also showed no significant differences between groups (MD: −0.11 s; SE: 0.06; 95% CI −0.25 to 0.02; $p = 0.099$). Individual responses and between-group differences are further illustrated using Cumming estimation plots (Figures S1–S8).

Anthropometric and body composition variables

A comparison between the experimental and control groups was conducted to assess changes from pre- to post-intervention (Table 1). Specifically, the creatine group showed a greater increase in body mass compared to the control group (MD: 1.07 kg; SE: 0.26; 95% CI 0.53 to 1.61; $p < 0.001$). Similarly, skeletal muscle mass increased significantly in the creatine group (MD: 1.50 kg; SE: 0.29; 95% CI 0.88 to 5.12; $p < 0.001$), along with total body water (MD: 1.76 kg; SE: 0.36; 95% C: 0.99 to 2.52; $p = 0.001$). In contrast, body fat mass decreased significantly in the creatine group compared to the control group (MD: −1.18 kg; SE: 0.42; 95% CI −2.06 to −0.30; $p = 0.01$). A significant

Table 1 Anthropometrics and physiological variables in healthy vegan participants with creatine supplementation and control group

Variables	Creatine pre ($N=10$)	Creatine post ($N=10$)	Control pre ($N=10$)	Control post ($N=10$)	Difference estimate (SE) [95% CI]	*P*-value
Body mass (kg)	67.7 ± 10.7	68.7 ± 10.9	67.8 ± 15.5	67.7 ± 15.5	1.07 (0.26) [0.53 to 1.61]	< 0.001
Skeletal muscle mass (kg)	29.9 ± 7.4	31.2 ± 7.9	30.6 ± 7.0	30.4 ± 7.1	1.5 (0.29) [0.88 to 5.12]	< 0.001
Body fat percentage (%)	21.4 ± 8.0	20.0 ± 8.1	18.5 ± 8.2	18.9 ± 8.8	−1.86 (0.62) [0.55 to 3.17]	0.0008
Body fat mass (kg)	14.1 ± 4.6	13.2 ± 4.8	13.1 ± 7.6	13.3 ± 7.9	−1.18 (0.42) [−2.06 to −0.3]	0.01
Body water (kg)	39.3 ± 8.9	40.7 ± 9.5	40.0 ± 8.4	39.6 ± 8.4	1.76 (0.36) [0.99 to 2.52]	0.001
Body mass index (kg/m^2)	22.2 ± 2.8	22.5 ± 2.7	22.7 ± 4.1	22.7 ± 4.1	1.89 (1.57) [−1.42 to 5.2]	0.245
Systolic blood pressure (mmHg)	120 ± 17.5	116 ± 14.1	116 ± 8.5	119 ± 12.6	−6.8 (4.88) [−17.1 to 3.45]	0.181
Diastolic blood pressure (mmHg)	72.3 ± 7.1	67.7 ± 8.0	72.7 ± 5.3	76.7 ± 9.1	−8.6 (2.74) [−14.4 to −2.85]	0.005
Heart rate (bpm)	64.2 ± 10.7	68.0 ± 12.6	62.0 ± 12.5	61.3 ± 15.9	4.6 (3.48) [−2.72 to 11.9]	0.203
Hydration (mOsm/kg)	1015 ± 6.2	1016 ± 7.1	1013 ± 7.5	1011 ± 5.2	3.3 (4.17) [−5.47 to 12.1]	0.439

Data are presented as mean ± standard deviation. Between-group differences correspond to the estimated group × time interaction derived from linear mixed-effects models and are expressed as mean difference (MD), standard error (SE), and 95% confidence interval (CI). P-values represent the significance of the group × time interaction. Negative values indicate greater reductions, whereas positive values indicate greater increases in the creatine group compared to placebo

Table 2 Macronutrient intake and dietary composition in healthy vegan participants with creatine supplementation and control group

Variables	Experimental pre ($N=10$)	Experimental post ($N=10$)	*p*-value	Control pre ($N=10$)	Control post ($N=10$)	*p*-value	Interaction effect (Time x Supplement)
Energy (Kcal)	2301.6 ± 222.7	2255.6 ± 266.3	0.323	2414.4 ± 263.4	2401.9 ± 298.9	0.987	0.366
Carbohydrates (%)	51.6 ± 2.5	52.2 ± 4.5	0.965	53.2 ± 4.6	53.4 ± 4.5	0.994	0.833
Carbohydrates (g)	296.8 ± 30.3	295.0 ± 47.3	0.994	327.2 ± 39.9	319.7 ± 38.4	0.712	0.647
Protein (%)	17.0 ± 1.3	17.5 ± 1.8	0.676	16.5 ± 1.5	16.4 ± 1.6	0.997	0.253
Protein (g)	89.2 ± 28.3	98.5 ± 14.0	0.576	92.0 ± 30.0	98.7 ± 15.4	0.820	0.829
Protein (g/kg/day)	1.5 ± 0.1	1.5 ± 0.1	1.000	1.5 ± 0.1	1.5 ± 0.1	0.972	0.780
Fat (%)	29.7 ± 2.5	29.2 ± 4.0	0.723	28.8 ± 4.3	28.8 ± 4.5	1.000	0.751
Fat (g)	70.0 ± 17.4	73.1 ± 12.8	0.956	74.9 ± 16.6	77.3 ± 17.0	0.841	0.914
Saturated fat (%)	4.8 ± 0.8	4.6 ± 0.9	0.824	4.5 ± 0.80	4.2 ± 0.9	0.491	0.917
Monounsaturated fat (%)	12.3 ± 2.1	12.7 ± 2.6	0.946	11.8 ± 1.6	10.9 ± 1.8	0.052	0.125
Polyunsaturated fat (%)	8.0 ± 2.3	7.7 ± 2.9	0.944	7.8 ± 3.4	9.1 ± 3.1	0.171	0.141

Data are presented as mean ± standard deviation. P-values within each group represent pre–post (within-group) comparisons, whereas the p-value in the interaction effect column indicates whether the magnitude of change differed between groups over time

Table 3 Physical performance variables in healthy vegan participants with creatine supplementation and control group

Variables	Experimental pre ($N=10$)	Experimental post ($N=10$)	Control pre ($N=10$)	Control post ($N=10$)	Difference estimate (SE) [95% CI]	*P*-value
30 m-sprint (s)	5.2 ± 0.5	5.07 ± 0.4	5.12 ± 0.6	5.08 ± 0.6	−0.11 (0.07) [−0.27 to 0.05]	0.1568
Isometric strength hand-dominant (kg)	34.8 ± 9.8	36.36 ± 9.8	37.54 ± 11.2	38.13 ± 9.9	0.89 (0.99) [− 1.18 to 2.98]	0.376
Isometric strength hand-non-dominant (kg)	34.1 ± 10.7	33.76 ± 8.9	34.18 ± 9.0	34.63 ± 8.2	−0.83 (1.57) [−4.13 to 2.47]	0.604
Countermovement jump (cm)	26.5 ± 6.9	29.51 ± 9.2	26.88 ± 6.3	27.13 ± 6.1	3.29 (1.22) [0.72 to 5.85]	0.015
Isometric mid-thigh pull (N)	2154.2 ± 724.2	2152.33 ± 618.9	2384.5 ± 751.5	2359.50 ± 680.4	68.4 (118) [−179 to 316]	0.568
15 jumps-flight time (s)	0.4 ± 0.1	0.43 ± 0.1	0.41 ± 0.1	0.42 ± 0.1	0.02 (0.003) [0.01 to 0.02]	< 0.001
15 jumps-contact time (s)	0.6 ± 0.1	0.55 ± 0.1	0.53 ± 0.2	0.54 ± 0.1	−0.11 (0.06) [−0.25 to 0.02]	0.099
15 jumps-height (cm)	20.6 ± 5.6	22.79 ± 5.8	21.28 ± 6.5	21.64 ± 6.0	1.87 (0.55) [0.67 to 3.06]	0.004

Data are presented as mean ± standard deviation. Between-group differences correspond to the estimated group × time interaction derived from linear mixed-effects models and are expressed as mean difference (MD), standard error (SE), and 95% confidence interval (CI). P-values represent the significance of the group × time interaction. Negative values indicate greater reductions, whereas positive values indicate greater increases in the creatine group compared to placebo

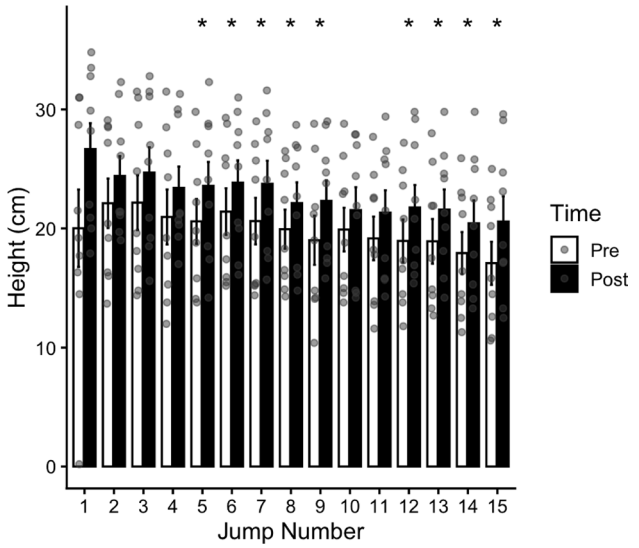


Fig. 2 Jump height across the repeated vertical jump test in the experimental group

reduction was also observed for diastolic blood pressure (MD: −8.6 mmHg; SE: 2.74; 95% CI −14.4 to −2.85; $p=0.005$).

Biochemical analysis

The experimental group exhibited a significant increase in serum creatinine and creatine concentrations following supplementation (Table S1). The interaction effect between time and supplementation group was significant for serum creatinine ($p<0.001$; $\eta^2p=0.93$), with the post-hoc analysis confirming a significant difference between pre- and post-intervention values in the creatine group ($p<0.001$). Similarly, a significant interaction was observed for serum creatine concentration ($p=0.008$; $\eta^2p=0.57$), with the post-hoc analysis revealing a significant increase between pre- and post-intervention values in the creatine group ($p=0.03$). Serum urea levels revealed a significant increase in the creatine supplementation group following the intervention period ($p=0.02$). However, no significant interaction effect was observed ($p=0.08$; $\eta^2p=0.30$). Finally, CK levels remained unchanged within groups ($p>0.05$), as no significant interaction effect was found ($p=0.29$; $\eta^2p=0.12$). No adverse events were reported during the study.

Discussion

This study investigated the effects of creatine supplementation on body composition, strength, and power performance in healthy adults following a vegan diet. Our results indicate that creatine supplementation (0.1 $g \cdot kg^{-1} \cdot day^{-1}$) in individuals consuming a vegan diet over 4 weeks significantly improved body composition and power performance variables compared to placebo. Specifically, creatine supplementation was associated with changes in skeletal muscle mass and reduced body fat percentage as well as improved lower-body explosive performance (e.g., greater jump height and flight time). These findings suggest that creatine supplementation is beneficial for individuals following a vegan diet.

The body composition changes observed in participants supplementing with creatine in the present study are consistent with previous reports on creatine supplementation and resistance training (Wu et al. 2022). Similarly, in individuals following a vegetarian diet, creatine supplementation has also been shown to increase body mass (Shomrat et al. 2000) and lean tissue mass compared to controls (Burke et al. 2003b). The increase in lean tissue mass demonstrated by those supplementing with creatine in the present study corresponds with the improvements seen in other lower-body power performance variables. The increased muscle phosphocreatine stores following creatine supplementation enhances phosphocreatine recovery, which has been suggested as a key factor for the improvement in work capacity during resistance training, ultimately contributing to increases in lean tissue mass (Gutiérrez-Hellín et al. 2025). In our study, participants did not follow a structured resistance training program but were asked to maintain their exercise routines. Also, creatine supplementation may enhance muscle mass gains by stimulating IGF-1 production, activating satellite cells, and reducing oxidative stress and inflammation, which protect against tissue damage (Louis et al. 2004; Sestili et al. 2011). Additionally, creatine increases energy stores through phosphocreatine and glycogen synthesis, supporting muscle performance and hypertrophy during resistance training (Safdar et al. 2008; Bonilla et al. 2021). Furthermore, despite the lack of significant differences in energy intake between the experimental and control groups, a reduction in fat mass was observed in the creatine-supplemented group. These findings, previously reported in omnivorous populations (Desai et al. 2024), are noteworthy as they suggest that creatine supplementation may contribute to increases in lean tissue mass and potentially support fat mass reduction, despite no changes in dietary energy intake. This could be attributed to increased energy expenditure during resistance training, as higher performance and muscle mass may lead to a higher basal metabolic rate (Arciero et al. 2001; MacKenzie-Shalders et al. 2020). While further research is required to explore the underlying mechanisms, this observation provides valuable insight into the potential body composition benefits of creatine supplementation beyond its effects on muscle mass.

Physical performance assessments revealed significant improvements in the creatine group, particularly in

lower-body explosive performance. These findings align with those previously reported in participants following an omnivorous diet (mielgo-ayuso et al. 2019; Wax et al. 2021; Vargas-Molina et al. 2022). However, evidence in vegetarians remains limited, with only a few studies evaluating the effects of creatine supplementation in this population. A study conducted on male vegetarians, including both individuals following a vegan and ovo-lacto vegetarian diet, reported that creatine supplementation for eight weeks led to an increase in total work for knee flexion and extension compared to the placebo (Burke et al. 2003b). Similar to our study, an increase in lean tissue mass and total body water was observed following creatine supplementation. This study used a loading phase of five days with 0.25 g of creatine/kg lean mass/day, followed by a maintenance phase of 0.0625 g of creatine/kg lean mass/day for 49 days (Burke et al. 2003b). Although a loading phase has traditionally been hypothesized to maximize the ergogenic benefits of creatine supplementation, as observed in our study, a chronic low-dose protocol also induces improvements in potential lower-body performance outcomes in individuals following a vegan diet (Antonio et al. 2021b). The present study demonstrates that a moderate-dose protocol without loading is sufficient to induce significant improvements in body composition and lower-body power performance.

In addition, creatine supplementation has been shown to enhance high intensity exercise performance. However, our results revealed no significant differences between groups in the 30 m sprint. Furthermore, we found no differences between groups for isometric handgrip strength, or isometric mid-thigh pull tests. These results support previous studies that analyzed high-intensity power performance in vegetarian and omnivorous populations (Watt et al. 2004; Marinho et al. 2024). For example, a maximal effort cycling test did not reveal significant changes in vegetarian subjects (4 vegans and 3 lacto-ovo vegetarians) after five days of creatine supplementation (Watt et al. 2004). However, significant differences were observed in the second bout of the intermittent sprint cycling test in this study, suggesting that the intervention may have influenced repeated bouts of high intensity exercise, possibly due to changes in fatigue accumulation or processes related to muscle recovery. Conversely, Shomrat et al. (Shomrat et al. 2000) observed a significant improvement in the Wingate all-out test in vegetarian subjects after creatine supplementation (3×7 g/d) for one week, with no differences compared to non-vegetarian subjects. However, in this study the diet was neither standardized nor monitored during the intervention, which makes it difficult to rule out potential changes in dietary intake and, consequently, exercise performance (Shomrat et al. 2000).

In terms of biochemical analysis, the experimental group demonstrated a significant increase in both serum creatinine and creatine concentrations following supplementation, indicating that creatine was absorbed. The significant interaction effects observed for serum creatinine and serum creatine further confirm the efficacy of the supplementation protocol. These results are consistent with studies showing that creatine supplementation results in elevated serum creatine and creatinine levels in vegetarians, reflecting an increase in stored creatine within muscles (Maccormick et al. 2004). The lack of significant changes in serum urea and CK levels between groups suggests that creatine supplementation did not negatively impact renal function in the short term. This supports its safety in individuals following a vegan diet, as has been reported in omnivorous populations (de Souza e Silva et al. 2019).

An important strength of this study was the standardization and monitoring of dietary intake and physical exercise, which effectively controlled for potential confounding factors and allowed for a clearer assessment of the effects of creatine supplementation. Additionally, the triple-blind design further minimized bias, enhancing the reliability of the findings by ensuring that neither the participants, the researchers, nor the data analysts were aware of group assignments. The analyses were designed to allow both per-protocol and intention-to-treat analyses, which is a strength because it enables evaluation of the efficacy of the supplementation under controlled conditions as well as its effectiveness under real-world scenarios. As there were no dropouts, both analyses yielded identical results. However, several limitations must be considered. The relatively small sample size ($n = 20$; 10 per group), although determined a priori, may limit the statistical power to detect small-to-moderate group × time interaction effects and reduce the generalizability of the findings. Therefore, results should be interpreted with caution. The success of blinding was not formally assessed, which may have influenced performance outcomes through expectancy effects. Although electrical bioimpedance analysis provides an estimation of skeletal muscle mass through segmental multifrequency bioelectrical impedance analysis, this parameter is derived from predictive algorithms rather than direct measurement and may be influenced by hydration status and other physiological factors. Therefore, these outcomes should be interpreted with caution. Moreover, the study did not include a long-term follow-up, which restricts the ability to assess the sustainability of the effects of creatine supplementation over time. Although total protein intake was controlled, protein quality and amino acid composition (e.g., arginine, glycine, and methionine), which are directly involved in endogenous creatine synthesis, were not assessed. This may have influenced individual variability in creatine metabolism and should be considered in future research. Additionally, differences were not assessed in comparison to individuals following an omnivorous diet,

preventing an understanding of whether the effects vary based on dietary patterns. Training characteristics and prior training history were not comprehensively quantified, which may influence individual responses to creatine supplementation and limit the interpretation of performance outcomes. Finally, despite the significant increase in serum creatine and creatinine concentrations, the study did not quantify muscle creatine levels, which would have provided a more direct assessment of the impact of creatine supplementation on muscle stores. However, previous studies have analyzed both serum and muscle creatine levels, finding significant increases following creatine supplementation, which further supports the validity of the observed serum changes (Blancquaert et al. 2018).

Conclusion

This study suggests that creatine supplementation can significantly impact body composition and physical performance in physically active individuals following a vegan diet, particularly in terms of increased skeletal muscle mass and improvements in lower-body muscular power. Furthermore, the findings support the safety of creatine supplementation, as indicated by the lack of significant changes in serum urea and creatine kinase levels. Future studies should include longer durations and comparisons with omnivorous populations to better understand the effects of creatine supplementation.

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Author contributions ML-M and J.G-H designed research; ML-M, J.G-H, A-M, MA-N, PM, conducted research; ML-M and AM analyzed data; and ML-M and AM wrote the paper; ML-M and SCF revised the paper. All authors read and approved the final manuscript.

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Data availability The data that support the findings of this study available from the corresponding author upon request.

Declarations

Conflict of interest ML-M reported receiving consulting fees from Danone and Foods For Tomorrow outside the submitted work. SCF is a scientific advisor for a creatine gummy company called Bear Balanced and has received creatine donations from Creapure for research purposes. All other authors report no conflicts of interest.

Ethical approval The research protocol was approved by the University Francisco de Vitoria.

Patient consent Written and verbal consent was obtained from all participants prior to enrolment in this investigation.

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