RBFEx
ISSN Online: 2675-1372

Revista Brasileira de Fisiologia do Exercício

Original article

Acute effect of creatine supplementation on morphofunctional parameters of vegan women

Efeito agudo da suplementação de creatina em parâmetros morfofuncionais em mulheres veganas

Juliana de Araújo Lisboa[1], João Henrique Gomes[1], Lorena Izabel Oliveira de Santana[1], Welmo Alcantara Barbosa[2], Roberta Luksevicius Rica[3], Danilo Sales Bocalini[2], Renata Rebello Mendes[1]

1. Universidade Federal de Sergipe, Aracaju, SE, Brazil
2. Universidade Federal do Espírito Santo, Vitória, ES, Brazil
3. Universidade Estácio de Sá, Vitória, ES, Brazil

ABSTRACT

Introduction: Creatine has been considered an ergogenic agent for omnivores and vegetarians, however, there is a significant gap in the effects of this supplementation on vegans' performance, the group with more restrictions amongst the vegetarians. **Aims:** To analyze the effect of creatine supplementation on performance in strength tests and body composition of vegan women. **Methods:** Fourteen non-athlete vegan women were randomly assigned to creatine group (n = 7) and placebo (n = 7). Before and after supplementation (0,3 g $kg^{-1}d^{-1}$ for 7 days), performance tests in *leg press* were done (3 series of maximum repetitions until failure, on 80% 1RM, 60 seconds interval), and anthropometry. **Results:** After supplementation, there were significant differences in the number of repetitions in the first series and in the sum of the three series for both groups, but with *effect size* and delta percentage higher for creatine group. There was no significant change in the participants' body composition. **Conclusion:** The creatine supplementation has greater effect on performance in lower limb strength tests, when compared to placebo, without affecting body composition.

Keywords: creatine; exercise; body composition

RESUMO

Introdução: A creatina tem sido considerada agente ergogênico para indivíduos onívoros e vegetarianos, porém, nota-se lacuna importante sobre o efeito dessa suplementação sobre a performance de veganos, grupo que apresenta maiores restrições nutricionais dentre os vegetarianos. **Objetivo:** Analisar o efeito da suplementação de creatina sobre performance em teste de força e composição corporal de veganas. **Métodos:** Quatorze veganas não-atletas foram randomicamente distribuídas em grupo creatina (n = 7) e placebo (n = 7). Antes e depois da suplementação (0,3 g kg^{-1} d^{-1} por 7 dias) foram realizados testes de performance em *leg press* (3 séries de repetições máximas até falha, a 80% de uma repetição máxima, 60 segundos de intervalo), e antropometria. **Resultados:** Após suplementação, houve diferenças significativa no número de repetições na primeira série e no somatório das três séries para ambos os grupos, porém, com o tamanho do efeito (*effect size*) e delta percentual superior para grupo creatina. Na segunda série, não houve diferenças significativas entre grupos e momentos, porém, *effect size* e delta percentual também foram superiores para grupo creatina. Não foi observada alteração significativa na composição corporal. **Conclusão:** A suplementação de creatina apresentou maior efeito sobre performance em teste de força para membros inferiores, quando comparadas ao placebo, sem alterar composição corporal.

Palavras-chave: creatina; exercício; composição corporal.

Received: March 10, 2020; Accepted: November 23, 2020.

Correspondence: Renata Rebello Mendes, Universidade Federal de Sergipe, Departamento de Nutrição (DNUT), Av. Marechal Rondon, s/n - Jardim Rosa Elze, 49100-000 São Cristóvão SE. remendes@academico.ufs.br

Introduction

Veganism is a type of vegetarianism that means having as a principle not to consume products that have resulted in the death and suffering of any animal, such as any type of meat, in addition to its derivatives, such as milk, eggs, honey. Currently, it is noticed that there is a greater spread of veganism and, gradually, this type of diet gains more followers for several reasons. Some of them are animal ethics, environmental awareness, religious reasons, and health care [1].

It is known that the adoption of this practice promotes alleged benefits, with emphasis on the improvement of immunity [1], as well as the prevention of chronic diseases such as obesity, hypertension, hyperlipemia, ischemic heart disease and diabetes, and of some types of cancer, such as prostate and gastrointestinal ones, especially colorectal cancer. However, despite the health benefits that veganism offers, the exclusion of so many food groups can also offer some nutritional risks [2]. Marine omega 3 (eicosapentaenoic acid - EPA, and docosahexaenoic acid - DHA), iron, zinc, vitamin B12, calcium, vitamin D and creatine are some potentially restricted nutrients in these diets, since their primary sources are derived from animals [2,3]

Some nutrients are directly or indirectly linked to exercise performance and recovery from physical effort [4-6], with emphasis on creatine. This nutrient plays an important role in energy metabolism, especially about exercise of maximum intensity and short duration, using mainly the anaerobic route [7,8]. In this way, the phosphocreatine reserves in the muscle are dephosphorylated, with the donation of a molecule free of inorganic phosphate (P) to the adenosine diphosphate molecule (ADP), to resuscitate ATP. Due to the high energy demand imposed by some types of physical exercise, this resynthesis may be limited, as the phosphocreatine stocks decrease. Therefore, it is believed that creatine supplementation can increase phosphocreatine stocks, maintaining ADP refosphorylation and, consequently, decreasing the decline in ATP resynthesis [7,9].

In a meta-analysis published by Lanhers *et al.* [10] a positive effect of creatine supplementation on the performance of strength exercises in the lower limbs was shown; however, the studies reviewed in this publication were conducted, mostly, with men and non-vegan athletes. Additionally, some studies show that vegetarians have reduced muscle creatine stores, and this supplementation is of great interest [11]. However, according to our surveys in databases the studies do not distinguish the type of vegetarianism, therefore, there are no specific reports on vegans. Such a gap is considered of extreme relevance, since veganism presents the greatest nutritional restrictions among vegetarians, and, therefore, the responses to creatine supplementation may be different. In this way, the objective of this study was to evaluate the effect of acute creatine supplementation on the performance and body composition of vegans from the city of Aracaju/SE. According to our hypothesis, vegans supplemented with creatine would show improvement in performance and increase in lean mass, compared to placebo, indicating that creatine could optimize performance in high intensity and short duration exercises in this group.

Methods

Sample

Forteen physically untrained adult women were evaluated, with mean age 24 ± 3.9 years, body mass 60.8 ± 14.2 kg and BMI 22.6 ± 5.2 kg/m². The mean time of veganism among them was 2.7 ± 1.5 years. This non-probabilistic sampling was performed for convenience, through recruitment on social networks. To start their participation, the volunteers signed the Free and Informed Consent Term, approved by the ethics committee of the Federal University of Sergipe (FUS) under the number 3.144.633

As inclusion criteria, participants should be female, declare themselves as vegan for a period of more than three months, not be consuming nutritional supplements that inferred sports performance and body composition in the last six months, as well as not having medical or injury that made it impossible to perform the physical test. As exclusion criteria, it was adopted the absence in any stage of evaluation of the present study, and the inadequate consumption of the proposed supplementation.

Table I - Sample characteristics

Parameters	CREA	PLA	p
Age (years)	23.7 ± 3.1	23.3 ± 2.3	0.837
Height (m)	1.67 ± 0.04	1.62 ± 0.06	0.144
Veganism time (years)	2.9 ± 1.6	2.4 ± 1.3	0.731
Maximal strenght (kg)	190.7 ± 77.9	202.3 ± 53.1	0.769

Values expressed as mean ± standard deviation. CREA = Creatine.; PLA = placebo

Experimental design

This is a randomized, double-blind clinical trial. The study design is outlined in figure 1.

Outcomes

The primary outcome was the performance of vegans in high intensity and short duration exercises, which was strength resistance. The body composition of the studied vegans was considered as a secondary outcome.

Randomization

After initial assessment, participants were randomized in a 1:1 ratio to creatine or placebo. To guarantee the confidentiality of the allocation list, an independent researcher performed the randomization, as well as being responsible for the organization of the vials for storing the supplements, which characterizes a double-blind study.

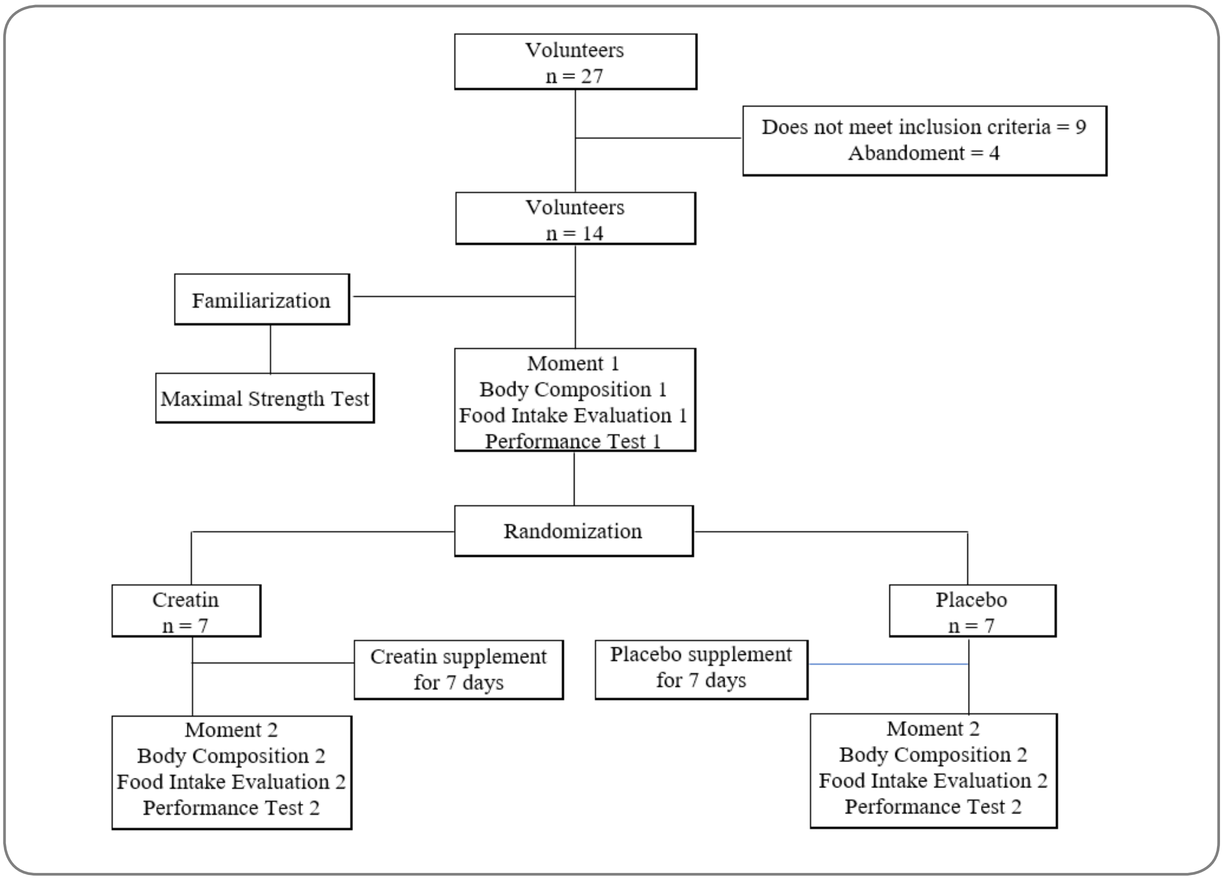


Figure 1 - Study design

Supplementation

Participants were randomly assigned to two groups and received supplements for seven days. To the creatine group (CREA, n = 7) the supplementation protocol was based on the recommendations of the International Society for Sports Nutrition - ISSN [9], which defines that the most effective way of ingesting creatine monohydrate for muscle saturation would be through the dose 0.3 g/kg of body weight, divided into four daily portions, maintained for 5 to 7 days. To placebo group (PLA, n = 7) the participants received the same doses mentioned above (0.3 g/kg), however, of maltodextrin

Considering the participants' body weight, the average daily consumption was 17.7 g of creatine monohydrate (CREA) and 18.8g of maltodextrin (PLA). To guarantee the double-blind methodology, the supplements adopted were free of dyes, flavors and flavorings, and similar in color and texture. The participants received detailed guidance on the protocol, being encouraged to take the four doses at prandial moments, considering the importance of the action of insulin in the muscular uptake of creatine through the CREA transporter

Maximal strength

To evaluate the maximum strength of the lower limbs and the maximum number of repetitions, with a load corresponding to 80% of 1 RM (one maximum repetition), the Leg press equipment (Physicus®) was used, belonging to the Department of Physical Education, *Universidade Federal de Sergipe* (DEF-UFS). Before the tests were performed, standardization and familiarization with the equipment was performed [12,13].

In standardization, each volunteer supported their feet on the platform in the most comfortable way and this position was marked on top of a masking tape fixed on that platform. In this way, the exact reproduction of the positioning of the feet was ensured throughout the data collection. Both the initial position (extended knees) and the final position (90º of the knee joint) of execution were measured to always repeat the same amplitude in subsequent tests. The volunteers visited the DEF-UFS gym, one week before the 1 RM test, and performed 3 series of 10 repetitions with progressive load increase (self-selected load), to familiarize themselves with the equipment and the effort to mechanical failure.

The test of 1 maximum repetition (1RM) followed these procedures: up to six attempts could identify the maximum weight that the volunteer could lift in one repetition, as suggested by Anderson and Kearney [14], with an interval of three minutes between them. Before performing the 1RM test, stretching or any other type of physical exercise was not allowed. The test was started with submaximal weights. With each attempt, the weight was increased with loads between 5 and 15 kg, until the mechanical failure was reached. The choice of the Leg press exercise was made since it is easy to prescribe, presenting little coordination requirement, in addition to being commonly prescribed in weight training programs [15]. Another factor considered in the choice of leg press was the results obtained in a recent meta-analysis [10], which showed the positive effect of creatine supplementation on the performance of lower limb strength exercises.

On the third visit, after a 48-hour rest from the 1RM test, the maximum number of repetitions possible was performed on the Leg press (Pre-supplementation: M1) with a weight corresponding to 80% of 1RM, in 3 series with a 1-minute interval recovery [14]. For data analysis, the sum of all series was used, as well as the number of repetitions in each series.

On the fourth visit (Post-supplementation: M2), after seven days of supplementation, the participants were again subjected to the test of maximum number of repetitions possible in the Leg press with the same load as the M1. During the seven days of supplementation, participants were asked to maintain their usual daily activities and abstain from strength exercises (weight training, functional training or Cross Fit) directed at the lower limbs. To minimize possible bias, performance tests were performed by the same trainer, at the same times and days of the week, with rest from any physical exercise 48 hours prior to the post-supplementation test (M2).

Body composition

To assess body composition, body weight and skinfolds were measured in triplicate, which were subsequently used to calculate the percentage of fat mass using the Jackson and Pollock equation [16], with 7 folds. The measurement of the folds

Rev Bras Fisiol Exerc 2021;20(2):268-282

was performed at Moment 1 and Moment 2, right after the weight was collected, before performing the performance tests.

Energy intake

The assessment of food intake was carried out using two 24-hour recalls, one performed in the pre-supplementation tests, and the other after, to assess possible changes in eating habits, potentially capable of interfering with the expected outcomes. The macronutrients and energy were analyzed using the DietBox program. The volunteers were instructed not to change their pattern of food consumption, as well as not to consume caffeine during supplementation, as evidence shows that caffeine, when ingested in high doses, can impair the ergogenic effect of creatine [17].

Statistical analyses

The assessment of food intake was carried out using two 24-hour recalls, one performed in the pre-supplementation tests, and the other after, to assess possible changes in eating habits, potentially capable of interfering with the expected outcomes. The macronutrients and energy were analyzed using the DietBox program. The volunteers were instructed not to change their pattern of food consumption, as well as not to consume caffeine during supplementation, as evidence shows that caffeine, when ingested in high doses, can impair the ergogenic effect of creatine [17].

Results

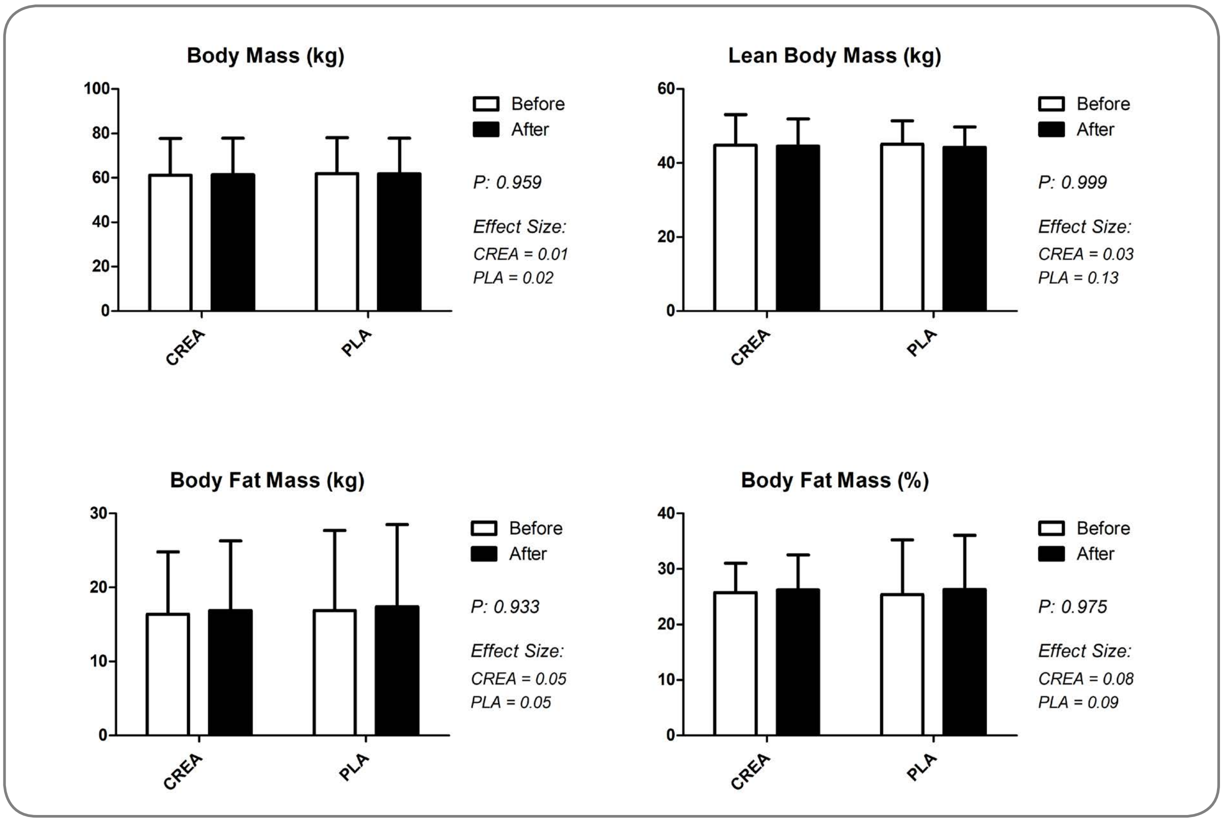
As described in Table II, both groups showed significant improvements in the number of repetitions in the first series ($p < 0.001$), as well as in the sum of repetitions ($p < 0.005$) after the supplementation period. However, according to the effect size, it is possible to observe that in these two variables, the effect for the creatine group was large (1.52 and 1.34, respectively), while for the placebo group, only moderate effects were observed (0.82 and 0.66, respectively), demonstrating, therefore, superiority in the effect caused by creatine supplementation. The percentage delta evaluation follows the same pattern as the effect size, with the CREA group values being higher than the PLA group, for the number of repetitions of the first series and the sum of repetitions.

Figure 2 shows the results of body composition. No significant differences were found between groups and moments.

Table II - Strength parameters before and after suplementation

Parameters	Before	After	Δ%	ES	Time p	Group*time p
1ª set (rep)						
CREA	11.8 ± 3.1	16.5 ± 2.4*	44.3	1.52	< 0.001	0.230
PLA	15.3 ± 4.9	19.3 ± 6.3*	26.6	0.82	< 0.001	
2ª set (rep)						
CREA	7.2 ± 2.6	9.2 ± 2.6	37.6	0.78	0.091	0.737
PLA	7.3 ± 2.6	8.2 ± 2.0	21.0	0.32	0.455	
3ª set (rep)						
CREA	4.5 ± 1.8	4.7 ± 1.6	7.1	0.09	0.787	1.000
PLA	4.5 ± 1.5	4.7 ± 2.3	4.6	0.11	0.787	
Total (rep)						
CREA	23.5 ± 5.1	30.3 ± 5.8*	29.8	1.34	< 0.001	0.487
PLA	27.2 ± 7.6	32.2 ± 8.2*	19.7	0.66	0.003	

Values expressed as mean ± standard deviation. CREA = Creatine; PLA = placebo. Δ% = percentage delta; ES = effect size; rep = repetitions



CREA = Creatine group; PLA = placebo group; P = p value of group*time analyses
Figure 2 - Body composition parameters before and after supplementation

Table III shows the intake of energy, protein and carbohydrate by vegans on the eve of the pre- and post-supplementation assessments, with no statistical differences between groups and moments.

Rev Bras Fisiol Exerc 2021;20(2):268-282

Table III - Intake energy of macronutrients before and after suplementation

Parameters	Before	After	Δ%	ES	Time p	Group*time p
Energy (calories)						
CREA	1760.5 ± 285.6	1720.4 ± 212.9	2.3	0.14	0.481	0.939
PLA	1703.3 ± 200.9	1756.3 ± 271.1	3.1	0.26	0.356	
Total protein (g)						
CREA	42.5 ± 15.8	42.5 ± 12.5	6.4	0.17	0.488	0.772
PLA	44.8 ± 9.0	46.6 ± 8.8	4.1	0.20	0.639	
Total carbohydrates (g)						
CREA	277.8 ± 50.4	263.0 ± 41.5	5.3	0.29	0.355	0.761
PLA	260.9 ± 37.8	264.1 ± 57.7	1.2	0.09	0.837	
Total fat (g)						
CREA	53.3 ± 21.7	54.2 ± 23.8	1.6	0.04	0.711	0.910
PLA	53.3 ± 19.7	57.1 ± 21.0	7.1	0.19	0.121	

Values expressed as mean ± standard deviation; CREA = Creatine; PLA = placebo; Δ%: percentage delta ES: effect size

Discussion

The main findings of the present study indicate that, although both groups showed a significant improvement in the number of repetitions in the first series and in the sum of the three series after supplementation, the CREA group presented magnitude of the effect size and delta% higher than the group PLA, thus suggesting the efficacy of creatine monohydrate supplementation, in daily doses of 0.3 g/kg, maintained for seven days, with regard to the performance in strength resistance test of lower limbs of vegan women, without however, promoting changes in body composition. According to our surveys, this was the first test with acute creatine supplementation, composed of an entirely vegan sample.

The 6.8 increase in the total number of repetitions in the CREA group allowed for an effect of large size (1.34), while the increase of 5.0 repetitions in the PLA group was moderate (0.66). In the same sense, the increase of 4.7 repetitions achieved in the first series in the CREA group had a large size effect (1.52) and in the PLA group, there was an increase of 4.0 repetitions, with a moderate effect (0.82). Such findings require caution when being analyzed, as in relation to the analyzed variable (number of maximum repetitions), it is worth mentioning that the difference in evolution in the first series (Post-Pre) between the groups, in absolute values (absolute delta), was only 0.7 repetitions, the CREA group being higher. In terms of the practice of sports training, depending on the intensity zone in which you are training, this difference can be insignificant from a physiological point of view, even if it is different from a statistical point of view.

The result of the second series showed no statistical difference after supplementation, in both groups. Even without statistical differences between the groups, it is worth noting that the CREA group increased 2.0 repetitions (moderate size effect) in the second series after supplementation, while the PLA group only 0.9 repetition (small size effect). From the physiological point of view, a difference of 1.1 in the increase in repetitions in the second series can play a relevant role in the training routine, because when training until mechanical failure, in a moderate zone of number of repetitions, characterized as a hypertrophic training zone [19], as was the second series (< 10RM), one more repetition can make a difference in the optimization of localized muscular resistance [20]. Thus, analyzing the study's findings from a physiological point of view the CREA group also presented results superior to PLA in the second series, corroborating the analysis of delta%, which was superior in CREA in relation to PLA.

The third series was not affected due to the time of the test execution, considering that in this series, other factors, independent of creatine stocks, were more relevant in the triggering of fatigue, such as metabolic acidosis, and glycogen depletion. It is important to highlight that, although they are all vegan, the sample presented different characteristics, such as differences in the level of training and sports practiced. These aspects must be considered to explain especially the discrepancies in the number of repetitions reached in the three sets up to the maximum effort [21]. In contrast, the randomization of participants allowed us to find normal data.

The supplementation protocol used in this study has been shown to be a useful strategy for increasing muscle creatine stocks. Kreider *et al.* [9] showed that ingesting 0.3 g/kg of body weight of creatine monohydrate (in four servings daily) for five to seven days is the most efficient way to increase muscle stores. Solis *et al.* [22] used the same protocol, which proved to be sufficient to increase muscle creatine in the group of vegetarians (9 lactovegetarians, 1 ovovegetarian and 4 vegans), and these had lower stocks compared to omnivores.

Blancquaert *et al.* [11] induced omnivorous women to vegetarianism, one group being supplemented with low doses of creatine (1 g/day) and the other with placebo. After three months, they observed a significant drop in the intramuscular stock of this nutrient and reported that the low dose of creatine was not enough to prevent the drop in stocks.

Lukaszuk *et al.* [23] found in their study that an ovolactovegetarian diet for 21 days reduces the creatine stocks in the muscle, and that a supplementation of 0.3 g/kg of creatine body weight maintained for 5 days was sufficient to increase these stocks both in the group vegetarians and omnivores.

The maximum limit of muscle creatine accumulation appears to be 160 mmol/kg of dry muscle in most individuals. A part of it is produced endogenously by the kidneys and liver (1-3 g/day), and another part is obtained by dietary consumption, using less meat and animal derivatives [9].

Recent studies have shown that vegetarians have lower muscle stocks of creatine, with about 90 to 110 mmol/kg of dry muscle and, for this reason, they can show higher gains in the muscle concentration of this nutrient after its supplementation, when compared to omnivores [22,24]. A limitation of the present study is the fact that it was not possible to quantify the muscle creatine concentrations of vegans by means of muscle biopsies; however, it is assumed that they would be even smaller than those found in ovolactovegetarians, since vegans exclude all animal derivatives from their diet.

About physical performance, there are few studies that have investigated the effects of creatine supplementation on the performance of vegetarians, regardless of the type of vegetarianism. Shomrat *et al.* [25] evaluated the effects of creatine supplementation, maintained for one week, on performance in maximum short-term exercise (modified Wingate test), comparing three groups: vegetarians supplemented with creatine, meat-eating individuals supplemented with creatine, and meat-eating subjects supplemented with placebo. From the results, the authors were able to conclude that both groups supplemented with creatine had a significant, and similar, improvement in performance after supplementation, while the placebo group did not show any ergogenic effect. However, there is an important difference in relation to our study, with the exercise protocol adopted by Shomrat *et al.* [25] who assessed anaerobic power.

Burke *et al.* [26] evaluated 42 volunteers, 24 non-vegetarians and 18 vegetarians, divided into four groups: vegetarians supplemented with creatine or placebo, and non-vegetarians supplemented with creatine or placebo. The aim was to investigate the effects of creatine supplementation on several variables, including creatine muscle concentration and performance in two types of tests: 1 RM and leg press. As a result, the authors found a significant increase in creatine stocks in groups supplemented with this nutrient, with a significantly greater increase in the vegetarian group. There was also a significant effect of creatine supplementation, in both groups supplemented with this nutrient, on the performance in the 1RM test, however, there were no significant differences between the four groups with regard to leg press.

It is important to note that in both works mentioned above [25,26] the samples were not composed exclusively by vegan individuals; considering that ovolactovegetarians consume some foods from animal sources, even though they provide reduced amounts of creatine, it is assumed that creatine stocks would be even lower in vegans [22]. Thus, vegans could have a different response to creatine supplementation since the diet has a direct influence on muscle creatine stores.

When evaluating the effect of creatine supplementation on performance in exercises performed by lower limbs, regardless of eating habits, it is possible to find a series of studies, including compiled in recently published meta-analysis [10]. However, most of the randomized clinical trials analyzed were conducted in men, and, according to Kreider *et al.* [9], when compared to men, women seem to present less significant responses to creatine supplementation, in terms of strength and lean mass gain.

Studies carried out with exclusively female samples, or partially composed of women, have shown conflicting results. Kambis and Pizzedas [27] showed an improvement in the muscular strength of the lower limbs of untrained adult women, supplemented with 0.5 g/kg of creatine monohydrate weight, for 5 days. Candow *et al.* [28] conducted a study with a sample of men and women, and both groups improved leg strength in the leg press, although the gains were greater in men. Gualano *et al.* [29] found an improvement in leg press strength in their study of elderly and vulnerable women after chronic creatine supplementation.

In contrast, Brenner, Rankin and Sebolt [30] chronically supplemented adult women (including some vegetarians) with creatine (5 g daily for 5 weeks), and found no improvement in lower limb strength, although they found significant improvements in upper limb tests. The authors hypothesized that the participants had a limited use of the potential of creatine in the lower limbs because they were trained in exercises that involve these limbs; this is because, it is known that regular training increases creatine concentrations in the recruited muscle fibers and, therefore, because there is a limit of creatine storage, fibers that are already in stock near the maximum limit have less capacity to capture the supplemented compound, consequently reducing its effectiveness [22,31].

The improvement in performance in strength exercises after supplementation with creatine has been explained by the important metabolic role that this nutrient plays in the anaerobic energy generation system; in the degradation of adenosine triphosphate (ATP) there is the release of ADP (adenosine diphosphate) and a phosphate-free molecule (P). This reaction is accompanied by a release of energy, which will be used in the exercise. For the process to continue, ADP molecules must be rephosphorylated and, during short-term, high-intensity exercises, creatine, in its phosphorylated form (phosphocreatine) is degraded, providing the P necessary for ATP resynthesis, and converting it on free creatine. Finally, the free creatine derived from this reaction, returns to the mitochondria, where it is phosphorylated again, and can be used again in the resynthesis of cytosolic ATP [7,31].

This system of synthesis and resynthesis of ATP with the aid of PCr, known as the ATP-CP system or of the phosphatens, has been considered essential to maintain the energy necessary for high intensity exercise and lasting less than 30 seconds. Therefore, situations of depletion of creatine stocks limit the rate of resynthesis of ATP, leading to muscle fatigue. If creatine supplementation can increase muscle phosphocreatine concentrations, there will be less decline in ATP resynthesis in the muscle and, consequently, delay in the onset of fatigue [7]. It is important to note that, in the present study, the PLA group showed an improvement in the number of repetitions in the first series in the leg press, as well as in the sum of repetitions of the three series, even if in magnitude lower than the CREA. The classic explanatory hypotheses for the placebo effect are divided into several categories, with emphasis on the explanation that associates this effect to the variation of neurological and brain chemical activity. In fact, a study has suggested that the analgesic effect of placebo involves both cognitive networks and endogenous opioid generation systems [32]. Therefore, the fatigue regulation center could be affected in the PLA group, which, according to Pollo, Carlino and Beneditti [33], although not yet identified, has been proposed as a brain center that integrates peripheral signals, such as heart and respiratory rhythm, serum lactate concentration, availability of carbohydrates, with the central control process, to protect the body from damage.

Additionally, the increase in the number of repetitions achieved in post-supplementation, in both groups, could also be justified by the learning effect, since untrained individuals or those with no experience in strength training may have a learning effect, even having performed familiarization sessions, regardless of the motor complexity and characteristic of the effort [12]. As a limitation of the performance test, the lack of control of the rhythm/speed of the concentric/eccentric actions by means of a digital metronome is pointed out.

Regarding the body composition of the participants, there were no significant changes in lean mass with supplementation. Our result corroborates the findings of other authors who evaluated the effect of acute creatine supplementation (5 to 7 days) on the body composition of non-athlete women [27,34]. The authors believe that, possibly, the absence of gains in lean mass is related to the short-term protocols used, which are insufficient to observe changes in body composition. In the work of Forbes *et al.* [35], women supplemented for five days with creatine followed by a maintenance period of 23 days with lower doses, submitted to 4 weeks of HIIT, also did not obtain changes in body composition. The authors believe that there was no hypertrophic response due to the absence of strength training and the fact that the participants are women, as some studies suggest that women have a lower response to creatine supplementation compared to men [28,36]. In contrast, most studies with creatine supplementation show an increase in lean mass in men, in general, related to factors such as modulation in the transcription of myogenic regulatory factors; efficiency in protein translation; activation, proliferation and differentiation of satellite cells; increased training volume or intensity due to the ergogenic effect [37].

It is essential to clarify the importance of gaining muscle strength for quality of life and sports performance. Recent studies have shown a positive impact of strength gain in reducing the risk of all causes of mortality [38], being a fundamental factor in the aging process [39]. From the point of view of sports performance, muscle strength is strongly associated with the improvement of the characteristics of the force-time curve, acting directly in increasing the ability to perform sports skills in general, such as jumping, running and changing direction activities, in addition to decrease the risk of injury [40].

Strategies that allow the optimization of muscle strength gain in vegan women are of paramount importance, as this population has shown growth worldwide and, in general, it is a lifestyle that tends to be adopted in the long term. This implies the engagement of such individuals in recreational physical exercise programs or sports, whether amateur or high-performance; additionally, even if they remain sedentary, with no objective of sports performance, vegan women can also benefit from gaining muscle strength, contributing to their longevity and quality of life [40].

We suggest carrying out future studies with a sample composed of vegan women, considering the effect of creatine supplementation on performance in strength exercises, seeking a larger sample number than that adopted in the present study, including investigating possible interferences of the sexual cycle of the participants in the moments of performance evaluation.

Conclusion

This study showed that acute creatine monohydrate supplementation, with a dose of 0.3 g/kg of body weight per day for 7 days, although not different in absolute values, had a greater effect on the performance of untrained vegan women in a resistance test of strength for lower limbs, when compared to placebo, without, however, changing the body composition. New studies considering a longer duration as well as an increase in the sample number is important for further clarification.

Acknowledgments
The authors thank Fundação de Amparo à Pesquisa e Inovação do Espírito Santo (590/19 – no. 84417625/2018) fellowships and to Department of Physical Education at the University of Sergipe, for offering its physical structure for the tests, and especially all participants for their dedication and commitment to the study.

Conflict of interest
No conflicts of interest with potential for this article have been reported.

Financing source
Fundação de Amparo à Pesquisa do Espírito Santo FAPES.

Authors' contributions
Conception and design of the research: Lisboa JA, Mendes RR, Gomes JH. **Data collection:** Lisboa JA, Santana LIO, Barbosa WA. **Analysis and interpretation of data:** Lisboa JA, Mendes RR, Gomes, JH, Santana LIO. **Statistical analysis:** Bocalini DS, Gomes JH. **Obtaining financing:** Lisboa JA. **Writing of the manuscript:** Lisboa JA. Mendes RR. **Critical review of the manuscript for important intellectual content:** Mendes RR, Gomes JH; Rica RL, Bocalini DS.

References

1. Kaviani M, Shaw K, Chilibeck PD. Benefits of creatine supplementation for vegetarians compared to omnivorous athletes: a systematic review. Int J Environ Res Public Health 2020;17. doi: 10.3390/ijerph17093041
2. Melina V, Craig W, Levin S. Position of the Academy of Nutrition and Dietetics: Vegetarian Diets. J Acad Nutr Diet 2016;1161970-80. doi: 10.1016/j.jand.2016.09.025
3. Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. J Acad Nutr Diet 2016;116:501-28. doi: 10.1016/j.jand.2015.12.006
4. Kerksick CM, Wilborn CD, Roberts MD, Smith-Ryan A, Kleiner SM, Jäger R, *et al*. ISSN exercise & sports nutrition review update: research & recommendations. J Int Soc Sports Nutr 2018;15:38. doi: 10.1186/s12970-018-0242-y
5. Rogerson D. Vegan diets: practical advice for athletes and exercisers. J Int Soc Sports Nutr 2017;14:36. doi: 10.1186/s12970-017-0192-9

6. Nebl J, Schuchardt JP, Ströhle A, Wasserfurth P, Haufe S, Eigendorf J, *et al.* Micronutrient status of recreational runners with vegetarian or non-vegetarian dietary patterns. Nutrients 2019;11. doi: 10.3390/nu11051146

7. Ydfors M, Hughes MC, Laham R, Schlattner U, Norrbom J, Perry CGR. Modelling in vivo creatine/phosphocreatine in vitro reveals divergent adaptations in human muscle mitochondrial respiratory control by ADP after acute and chronic exercise. J Physiol 2016;594:3127-40. doi: 10.1113/JP271259

8. Hummer E, Suprak DN, Buddhadev HH, Brilla L, San Juan JG. Creatine electrolyte supplement improves anaerobic power and strength: a randomized double-blind control study. J Int Soc Sports Nutr 2019;16:24. doi: 10.1186/s12970-019-0291-x

9. Kreider RB, Kalman DS, Antonio J, Ziegenfuss TN, Wildman R, Collins R, *et al.* International Society of Sports Nutrition position stand : safety and efficacy of creatine supplementation in exercise , sport , and medicine. J Int Soc Sports Nutr 2017;14:1-18. doi: 10.1186/s12970-017-0173-z

10. Lanhers C, Pereira B, Naughton G, Trousselard M. Creatine supplementation and lower limb strength performance : a systematic review and meta-analyses. Sports Med 2015;45(9):1285-94. doi: 10.1007/s40279-015-0337-4.

11. Blancquaert L, Baguet A, Bex T, Volkaert A, Everaert I, Delanghe J, *et al.* Changing to a vegetarian diet reduces the body creatine pool in omnivorous women, but appears not to affect carnitine and carnosine homeostasis: a randomised trial. Br J Nutr 2018;119:759-70. doi: 10.1017/S000711451800017X

12. Dias RMR, Avelar A, Menêses AL, Salvador EP, Silva DRP, Cyrino ES. Segurança, reprodutibilidade, fatores intervenientes e aplicabilidade de testes de 1-RM. Mot Rev Educ Física 2013;19:231-42. doi: 10.1590/S1980-65742013000100024

13. Chagas MH, Barbosa JRM, Lima FV. Comparação do número máximo de repetições realizadas a 40 e 80 de uma repetição máxima de dois diferentes exercícios na musculação entre os gêneros masculino e feminino. Rev Bras Educ Fís Esp 2005;19:5-12. doi: 10.1590/S1807-55092005000100001

14. Anderson T, Kearney JT. Effects of three resistance training programs on muscular strength and absolute and relative endurance. Res Q Exerc Sport 1982;53:1-7. doi: 10.1080/02701367.1982.10605218

15. Chrusch MJ, Chilibeck PD, Chad KE, Davison KS, Burke DG. Creatine supplementation combined with resistance training in older men. Med Sci Sports Exerc 2001;33: 2111-7. doi:10.1097/00005768-200112000-00021

16. Jackson AS, Pollock ML, Ward A. Generalized equations for predicting body density of women. Med Sci Sports Exerc 1980 [Internet];12:175-81. [cited 2020 Jan 20]. Available from: http://www.ncbi.nlm.nih.gov/pubmed/7402053

17. Buford TW, Kreider RB, Stout JR, Greenwood M, Campbell B, Spano M, *et al.* International Society of Sports Nutrition position stand: creatine supplementation and exercise. J Int Soc Sports Nutr 2007;4:6. doi: 10.1186/1550-2783-4-6

18. Hopkins WG. A scale of magnitudes for effect statistics. Sportscience [Internet] 2002;5:1-7. [cited 2020 Jan 15]. Available from: http://www.sportsci.org/resource/stats/

19. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee I-M, *et al.* Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults. Med Sci Sport Exerc 2011;43:1334-59. doi: 10.1249/MSS.0b013e318213fefb

20. Izquierdo M. Differential effects of strength training leading to failure versus not to failure on hormonal responses, strength, and muscle power gains. J Appl Physiol 2006;100:1647-56. doi: 10.1152/japplphysiol.01400.2005

21. Julio UF, Panissa VLG, Franchini E. Predição da carga máxima a partir do número máximo de repetições com cargas submáximas para mulheres. Rev Bras Cineantropom Desempenho Hum 2011;13. doi: 10.5007/1980-0037.2011v13n5p361

22. Solis MY, Artioli GG, Otaduy MCG, Leite CC, Arruda W, Veiga RR, *et al.* Effect of age, diet, and tissue type on PCr response to creatine supplementation. J Appl Physiol 2017;123:407-14. doi: 10.1152/japplphysiol.00248.2017

23. Lukaszuk JM, Robertson RJ, Arch JE, Moore GE, Yaw KM, Kelley DE, *et al.* Effect of creatine supplementation and a lacto-ovo-vegetarian diet on muscle creatine concentration. Int J Sport Nutr Exerc Metab 2002;12:336-48. doi: 10.1123/ijsnem.12.3.336

24. Watt KKO, Garnham AP, Snow RJ. Skeletal muscle total creatine content and creatine transporter gene expression in vegetarians prior to and following creatine supplementation. Int J Sport Nutr Exerc Metab 2004;14:517-31. doi: 10.1123/ijsnem.14.5.517

25. Shomrat A, Weinstein Y, Katz A. Effect of creatine feeding on maximal exercise performance in vegetarians. Eur J Appl Physiol 2000;82:321-5. doi: 10.1007/s004210000222

26. Burke DG, Chilibeck PD, Parise G, Candow DG, Mahoney D, Tarnopolsky M. Effect of creatine and weight training on muscle creatine and performance in vegetarians. Med Sci Sport Exerc 2003;35:1946-55. doi: 10.1249/01.MSS.0000093614.17517.79

27. Kambis KW, Pizzedaz SK. Short-term creatine supplementation improves maximum quadriceps contraction in women. Int J Sport Nutr Exerc Metab 2003;13:87-96. doi: 10.1123/ijsnem.13.1.87

28. Mihic S, MacDonald JR, McKenzie S, Tarnopolsky MA, Candow DG, Chilibeck PD, *et al.* Effect of different frequencies of creatine supplementation on muscle size and strength in young adults. Med

Sci Sports Exerc 2000;32:1831-8. doi: 10.1097/00005768-200002000-00007

29. Gualano B, Macedo AR, Alves CRR, Roschel H, Benatti FB, Takayama L, *et al.* Creatine supplementation and resistance training in vulnerable older women: A randomized double-blind placebo-controlled clinical trial. Exp Gerontol 2014;53:7-15. doi: 10.1016/j.exger.2014.02.003

30. 30. Brenner M, Walberg Rankin J, Sebolt D. The effect of creatine supplementation during resistance training in women. J Strength Cond Res 2000;14:207. doi: 10.1519/1533-4287(2000)014<0207:TEOCSD>2.0.CO;2

31. Mendes RR, Pires I, Oliveira A, Tirapegui J. Effects of creatine supplementation on the performance and body composition of competitive swimmers. J Nutr Biochem 2004;15:473-8. doi: 10.1016/j.jnutbio.2003.12.012

32. Petrovic P. Placebo and opioid analgesia - imaging a shared neuronal network. Science 2002;295:1737-40. doi: 10.1126/science.1067176

33. Pollo A, Carlino E, Benedetti F. Placebo mechanisms across different conditions: from the clinical setting to physical performance. Philos Trans R Soc B Biol Sci 2011;366: 1790-98. doi: 10.1098/rstb.2010.0381

34. Hamilton KL, Meyers MC, Skelly WA, Marley RJ. Oral creatine supplementation and upper extremity anaerobic response in females. Int J Sport Nutr Exerc Metab 2000;10: 277-89. doi: 10.1123/ijsnem.10.3.277

35. Forbes SC, Sletten N, Durrer C, Myette-Côté É, Candow D, Little JP. Creatine monohydrate supplementation does not augment fitness, performance, or body composition adaptations in response to four weeks of high-intensity interval training in young females. Int J Sport Nutr Exerc Metab 2017;27:285-92. doi: 10.1123/ijsnem.2016-0129

36. Mihic S, MacDonald JR, McKenzie S, Tarnopolsky MA. Acute creatine loading increases fat-free mass, but does not affect blood pressure, plasma creatinine, or CK activity in men and women. Med Sci Sports Exerc 2000;32:291-6. doi: 10.1097/00005768-200002000-00007

37. Lobo DM, Tritto AC, Silva LR, Oliveira PB, Benatti FB, Roschel H, *et al.* Effects of long-term low--dose dietary creatine supplementation in older women. Exp Gerontol 2015;70:97-104. doi: 10.1016/j.exger.2015.07.012

38. García-Hermoso A, Cavero-Redondo I, Ramírez-Vélez R, Ruiz JR, Ortega FB, Lee D-C, *et al.* Muscular strength as a predictor of all-cause mortality in an apparently healthy population: a systematic review and meta-analysis of data from approximately 2 million men and women. Arch Phys Med Rehabil 2018;99:2100-2113.e5. doi: 10.1016/j.apmr.2018.01.008

39. Li R, Xia J, Zhang XI, Gathirua-Mwangi WG, Guo J, Li Y, *et al.* Associations of muscle mass and strength with all-cause mortality among us older adults. Med Sci Sports Exerc 2018;50:458-67. doi: 10.1249/MSS.0000000000001448

40. Suchomel TJ, Nimphius S, Stone MH. The importance of muscular strength in athletic performance. Sports Med 2016;46(10):1419-49. doi: 10.1007/s40279-016-0486-0