



Pre-workout supplementation of capsaicin does not increase resistance training performance in a multiexercise protocol in trained men

original paper

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IGOR C.S. FONSECA^{ID}, VERNON M. CRUZ^{ID}, MARIANA FONSECA^{ID}, RONALDO A.D. SILVA^{ID}, CAROLINA B. SIMÕES^{ID}, PAULA L.C. GOMES^{ID}, MARCOS D.M. DRUMMOND^{ID}

Federal University of Minas Gerais (UFMG), School of Physical Education, Physiotherapy, and Occupational Therapy (EEFFTO), Department of Sports, Laboratory of Nutrition and Sports Training (LAN), Belo Horizonte, Minas Gerais, Brazil

ABSTRACT

Purpose. The aim of this study was to investigate the acute effect of capsaicin supplementation on performance, perceived exertion, and perceived effects in a resistance training protocol for the lower body.

Methods. The sample was 14 young men (22.21 ± 2.55 years; 82.35 ± 5.16 kg; 174 ± 0.7 cm; $9.08 \pm 2.73\%$ of body fat), with 4.19 ± 2.98 years of experience in resistance training. The study design was randomised, double-blind and crossover. The subjects performed the training protocol after consuming Capsaicin (12 mg) (CAP) or a placebo (PLA). The training protocol was: five sets of Back Squats and Leg Presses 45° , with 70% of 1RM until failure. The interval between sets was 90 seconds and 120 seconds between exercises. The number of maximum repetitions (NMR) and the rate of perceived exertion (RPE) were recorded after each set.

Results. The paired *t*-test showed that there was no statistically significant difference between PLA and CAP in the mean NMR ($p = 0.251$; 95%CI = $-5.47 - 19.18$), mean session volume load (VL) (weight lifted \times NMR) ($p = 0.117$; 95%CI = $-582.70 - 4639.99$) and in the mean RPE ($p = 0.458$; 95%CI = $-0.81 - 0.39$).

Conclusions. The acute capsaicin supplementation did not change the perception of vigour and side effects. Therefore, pre-workout capsaicin supplementation did not alter performance, RPE, or perceived effects in a lower body multi-exercise training protocol in trained men.

Key words: sports nutrition, ergogenic substance, muscle hypertrophy

Introduction

Pre-workout supplementation can acutely increase the training session performance and, consequently, can enhance chronic training results [1]. In view of this, the scientific literature has searched for substances, isolated or combined, that can increase strength, power and endurance in resistance training [2–3]. Thus, the ingestion of capsaicinoids, a class of substances found in peppers, has been shown to increase the release of calcium in the sarcoplasm [4], norepinephrine, energy expenditure and lipolysis [5] in humans.

A substance in this class with a potential ergogenic effect on resistance training is capsaicin. Capsaicin is a substance present in peppers and other spicy foods and the main chemical responsible for the pungent characteristic of these foods. Capsaicin acts as an agonist of the Transient Receptor Potential Vanilloid Type 1 (TRPV1), which generates several physiological responses, including increased release of acetylcholine in the neuromuscular junction and calcium in the sarcoplasmic reticulum, in addition to greater stimulation of the central nervous system (CNS), pain tolerance and less mobilisation of muscle glycogen reserves [6].

Correspondence address: Marcos D.M. Drummond, Laboratory of Nutrition and Sports Training (LAN), Department of Sports, School of Physical Education, Physiotherapy, and Occupational Therapy (EEFFTO), Federal University of Minas Gerais (UFMG), Av. Presidente Antônio Carlos, 6627, Pampulha, MG, 31270-901, Belo Horizonte, Brazil, e-mail: zangmarcos@gmail.com; <https://orcid.org/0000-0002-5622-1297>

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Capsaicin also has an analgesic potential, since the activation and desensitisation of TRPV-1 regulates nociception, which can decrease the perception of discomfort and effort during exercise [7]. Such effects can positively influence resistance training performance.

Freitas et al. [4] found that the acute supplementation of 12 mg of capsaicin increased the numbers of maximum repetitions (NMR) performed and reduced the perceived exertion (RPE) in male trained individuals in resistance training. The training protocol was 4 sets until muscle failure, with 70% of one repetition maximum (1RM) in the back squat exercise. Similar results were found by Freitas et al. [8], who also investigated the supplementation of 12 mg of capsaicin in the same resistance training protocol but performed after high-intensity intermittent exercise.

The possible positive effect of pre-workout capsaicin supplementation on resistance training can promote greater muscle hypertrophy, mainly due to the increase in training volume [4]. However, there were no studies found that investigated the effect of capsaicin supplementation in resistance training with multiple exercises and sets of protocols, that could be more effective for muscle hypertrophy in trained individuals [9].

However, Capsaicin supplementation can cause some side effects, such as nausea, gastrointestinal discomfort and abdominal cramps, possibly related to individual tolerance and doses [10]. Freitas et al. [4] state that the 12 mg dose does not lead to the perception of side effects in acute capsaicin supplementation. Simões et al. [11] did not find that pre-workout supplementation with 12 mg capsaicin causes side effects in the same resistance training protocol as Freitas et al. [4]. However, no other studies have investigated the side effects of capsaicin supplementation before multiple exercise and sets resistance training.

Thus, the present study aimed to investigate the effect of pre-workout capsaicin supplementation on re-

sistance training performance, in a protocol with multiple exercises and sets, and possible side effects, in trained individuals. The hypothesis was that supplementation would increase performance in weight training without causing side effects.

Material and methods

Experimental design

The study design was randomised, double-blind and crossover. The volunteers performed six experimental sessions. The interval between sessions was one week. In the first session, the study project was presented and explained to the volunteers. The second session served to characterise the volunteers and familiarise them with the equipment and tests. They also completed rating (RPE) and perceived effects questionnaires (PEQ). Finally, in this session, 24-hour dietary recall was performed to characterise the volunteers' diets [11]. In the third session, the 1RM test was performed in the Back Squat exercise. In the fourth session, the 1RM test was performed in the Leg Press 45° exercise. In the fifth and sixth sessions, the volunteers consumed capsaicin or a placebo, randomised, followed by the resistance training protocol. Also, the (NMR) performed and RPE at each set, volume load (VL), PEQ responses and 24-hour dietary recall were recorded in these last two experimental sessions, for later comparison. The experimental design is shown in Figure 1. All experimental sessions were performed at the same time of day for each volunteer, in order to minimise possible time of day interference.

Subjects

The study sample was 14 young men (22.21 ± 2.55 years; 82.35 ± 5.16 kg; 174 ± 0.7 cm; $9.08 \pm 2.73\%$

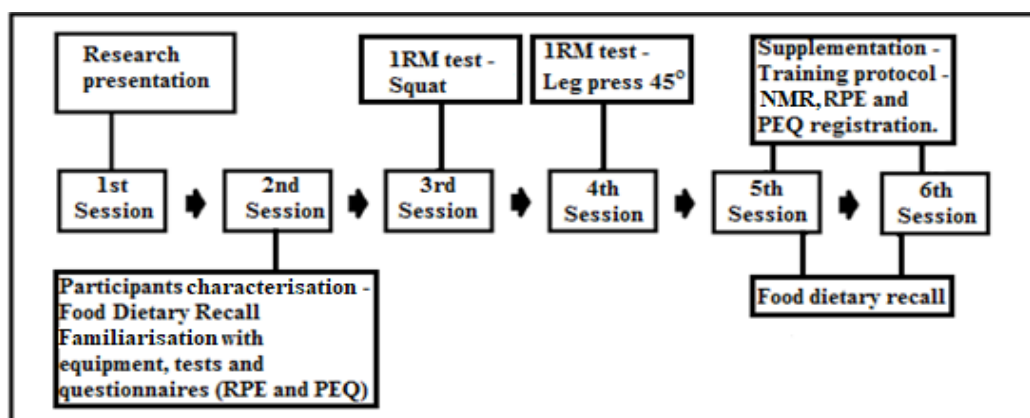


Figure 1. Experimental design. Source: elaborated by the author

of body fat), with a mean experience of 4.19 ± 2.98 years in resistance training, with a minimum frequency of three times a week.

The inclusion criteria were: the volunteers should have experience in resistance training of at least 12 months and experience performing the exercises proposed in the training protocol until concentric failure.

Exclusion criteria were: history or presence of injuries or medical conditions that could interfere in the performance of the exercises, as well as the use of capsaicin, such as food allergies or gastrointestinal disorders. Volunteers could not be users in the last 12 months of ergogenic resources or regular medications. During the study, participants were instructed not to use any other supplement or ergogenic aid, as well as not to make changes in their diet and training routine.

Procedures

The experimental sessions were performed in the auditorium, strength training centre and/or in the nutrition clinic of the Sports Training Center (CTE) of the Federal University of Minas Gerais (UFMG).

Anthropometric measurements and body composition

The body mass and height of the volunteers were measured using a Welmy brand scale (model W200/5 class III, Santa Bárbara d'Oeste, São Paulo, Brazil), with a precision of 0.1 kg and 0.1 cm. The percentage of body fat was measured using the seven-fold protocol [12] with an adipometer (Cescorf, Inovare 4, Tristeza, Porto Alegre, Brazil). The skin folds were always measured by the same evaluator.

Assessment of food consumption

The volunteer diet was monitored with 24-hour dietary recalls performed prior to the second, fifth, and sixth experimental sessions. The volunteers were instructed to replicate the meal prior to the experimental sessions, which should be consumed one (1) hour before of the session. They were also instructed to not consume peppers or other spicy foods, coffee, alcohol, or stimulating drinks for a period of 12 hours before the experimental sessions. These procedures were similar to those adopted by Simões et al. [11] to promote the maintenance of the volunteer dietary pattern during the research, in addition to minimising possible differences between food consumption in placebo and capsaicin situations. If a difference above 5% was found

in the intake of energy and macronutrients (carbohydrates, lipids and proteins), the volunteer would be removed from the sample. Such exclusion was not necessary. The mean energy intake in the volunteers' diet was $2,446.5 \pm 353.4$ kcal and the proportion of the macronutrients mean ingestion was $50.4 \pm 5.1\%$ (3.8 ± 1.2 g/kg) of carbohydrates, $31.8 \pm 4.4\%$ (1.3 ± 0.7 g/kg) of lipids and $18.4 \pm 5.7\%$ (1.6 ± 0.5) of proteins. This nutritional assessment was performed by a nutrition professional expert researcher. The online software Dietbox (version 2.0, Brazil) was used to register the 24-hour dietary recalls and calculate the energy and intake of macronutrients.

Familiarisation

The volunteers were introduced to the resistance training centre, exercises, equipment and 1RM test protocol. The exercises used were the Back Squat and Leg Press. In the 1RM test familiarisation, the procedures adopted were the same as those used by Fonseca et al. [13].

The Back Squat was executed with an Eleiko brand Olympic-type bar (model IWF WEIGHTLIFTING TRAINING BAR, MEN, Halmstad, Sweden) weighing 20 kg on a Gladius brand support (Power Rack Colosseum model, Fortaleza, Brazil). In the Leg Press, a Technogym brand machine (Pure model – Linear Leg Press, Rio de Janeiro, Brazil) was used. The mass lifted (between 1.25 and 25 kg) (Ziva, Curitiba, Paraná, Brazil) was measured before each experimental session.

1RM test protocol

The 1RM test protocol was similar to that performed by Drummond et al. [14] and Fonseca et al. [13]. The participants were requested to complete a repetition with the weight lifted in the two exercises during the familiarisation session. After a 5-minute rest, the weight was raised by 5 to 15% based on the participants' and researchers' perceived exertion [14]. Then, the volunteers were requested to perform one more repetition. This was repeated until the participant could not perform a complete repetition. The value of 1RM was considered as the weight lifted in the previous attempt, not exceeding five attempts in the same test session [14]. More than one session was not required to find the 1RM of any volunteers.

Performing the exercises followed the same procedures adopted by Fonseca et al. [13]. The determination and control of the standardised joint angles in the exercises was performed with the Angle Meter 360

mobile phone application (Version 1.7; IOS; Brazil). Volunteers were instructed to not perform vigorous physical activities 72 hours before the test sessions.

Supplementation protocol

The volunteers consumed, double-blind and randomised, one capsule containing 12 mg capsaicin (CAP) or a placebo (PLA) (20 mg of starch). The capsules were identical. The 12 mg dose of CAP was adopted based on the results of the studies of Freitas et al. [4] and Freitas et al. [8], which found positive acute effects in the supplementation of this substance in resistance training sessions (increase in VL). The volunteers performed the training protocol 45 minutes after swallowing without chewing the capsule [4].

Training session protocol

The volunteers performed a warm-up protocol consisting of five (5) minutes of walking on the CTE athletics track, followed by the execution of 10 repetitions in the Back Squat with weight corresponding to 50% of 1RM [4]. The walking speed was controlled by the volunteer, who was only instructed to perform it at light intensity.

After the warm-up protocol, the volunteers rested for five (5) minutes. During the break, the safety bars and a wooden bench were adjusted and positioned to control the range of motion and increase safety. Posteriorly, the volunteers performed five (5) sets of NMR of the Back Squat, with 70% of 1RM followed by five (5) sets of NMR on the Leg Press 45°, also with 70% of 1RM. The pause adopted between sets was 90 seconds and the pause between exercises was 120 seconds.

The VL performed was determined by NMR multiplied by the displaced mass (repetitions \times displaced mass) in all sets [4].

After the end of each set, the volunteers indicated the RPE. The procedures for recording RPE were the same as those adopted by Freitas et al. [4].

As in the 1RM test sessions, the volunteers were instructed not to perform vigorous physical activities 72 hours before the training sessions, especially activities that required recruitment of the lower body.

Perceived effects questionnaire (PEQ)

The PEQ applied is the same as the one adopted by Wilk et al. [15]. It is a questionnaire with 8 effects, to be answered with 'yes' or 'no', based on the volunteer's perception. Possible effects reported are increased vig-

our/activity; headache, intestinal or abdominal discomfort, muscle pain, tachycardia or heart palpitation, insomnia, increased urine production, and increased anxiety.

The PEQ was applied 15 minutes before the training protocol, and repeated 15 minutes and 24 hours after the training protocol [15].

Statistical analysis

Data normality was verified using the Shapiro-Wilk test. To compare the NMR and volume load between the placebo and capsaicin participants, the paired *t*-test was performed, and the effect size, when a difference was verified, was calculated according to Rhea [16] for trained individuals. Side effects were analysed using the Chi-Square test. Descriptive data analysis to summarise the results of the study variables are presented as mean \pm standard deviation, confidence interval (95%CI) and percentage values. In all statistical tests, the significance level adopted was $\alpha = 0.05$ and for data analysis, the SPSS software version 20.0 was used.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and, as integrated into an institutional project, has been approved by the Research Ethics Committee of the Federal University of Minas Gerais (4.233.313). This project complied with all the norms established by the National Health Council (Res 466/2012).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

The data distribution was normal. The paired *t*-test showed that there was no statistically significant difference in the VL of the experimental session ($p = 0.117$; 95%CI = $-582.70 - 4639.99$) between PLA ($18,254 \pm 5,749$ kg) and CAP ($16,225 \pm 5,033$ kg) situations (Figure 2). When analysing the NMR in the PLA (98.85 ± 24.27) and CAP (92.00 ± 23.32), the statistical difference was not significant either ($p = 0.251$; 95%CI = $-5.47 - 19.18$) (Figure 3). The individual responses of the VL and NMR in relation to the means are shown in Figure 2 and Figure 3, respectively.

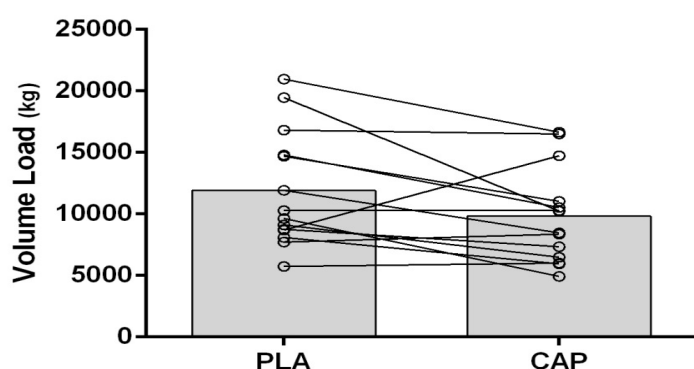


Figure 2. Individual Volume load (mass × repetitions) of the placebo and capsaicin participants

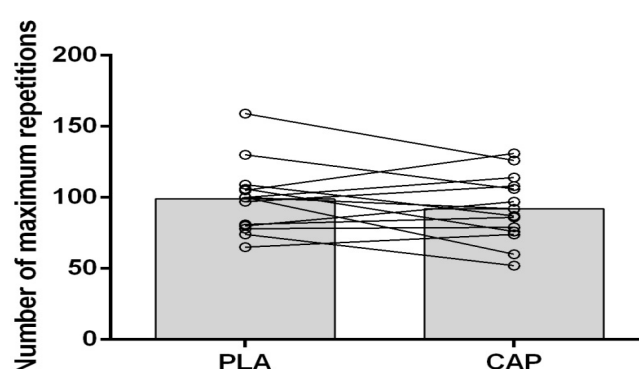


Figure 3. Individual number of maximum repetitions of the placebo and capsaicin participants

Table 1. Effects perceived 15 minutes before, 15 minutes after and 24 hours after the training session

	Capsaicin (n = 14)		Placebo (n = 14)		p-value
	Yes	Not	Yes	Not	
Pre increased vigour	0 (0%)	14 (100%)	1 (7%)	13 (93%)	0.308
Increased vigour 15'	3 (21%)	11 (79%)	2 (14%)	12 (86%)	0.621
24h increase in vigour	1 (7%)	13 (93%)	0 (0%)	14 (100%)	0.308
Pre headache	0 (0%)	14 (100%)	0 (0%)	14 (100%)	AT
Headache 15'	2 (14%)	12 (86%)	1 (7%)	13 (93%)	0.541
24h headache	0 (0%)	14 (100%)	1 (7%)	13 (93%)	0.308
Pre intestinal discomfort	2 (14%)	12 (86%)	1 (7%)	13 (93%)	0.541
Intestinal discomfort 15'	0 (0%)	14 (100%)	1 (7%)	13 (93%)	0.308
Intestinal discomfort 24h	0 (0%)	14 (100%)	2 (14%)	12 (86%)	0.142
Pre muscle pain	0 (0%)	14 (100%)	0 (0%)	14 (100%)	AT
muscle pain 15'	9 (65%)	5 (35%)	6 (43%)	8 (57%)	0.255
24h muscle pain	11 (79%)	3 (21%)	8 (57%)	6 (43%)	0.224
Pre tachycardia	0 (0%)	14 (100%)	1 (7%)	13 (93%)	0.308
15' tachycardia	0 (0%)	14 (100%)	2 (14%)	12 (86%)	0.142
24h tachycardia	0 (0%)	14 (100%)	1 (7%)	13 (93%)	0.308
Insomnia pre	0 (0%)	14 (100%)	0 (0%)	14 (100%)	AT
Insomnia 15'	0 (0%)	14 (100%)	0 (0%)	14 (100%)	AT
Insomnia 24h	0 (0%)	14 (100%)	0 (0%)	14 (100%)	AT
Pre increased urine	0 (0%)	14 (100%)	0 (0%)	14 (100%)	AT
Increased urine 15'	0 (0%)	14 (100%)	0 (0%)	14 (100%)	AT
Increased urine 24h	0 (0%)	14 (100%)	2 (14%)	12 (86%)	0.142
Pre increased anxiety	1 (7%)	13 (93%)	2 (14%)	12 (86%)	0.541
Increased anxiety 15'	0 (0%)	14 (100%)	1 (7%)	13 (93%)	0.308
Increased anxiety 24h	2 (14%)	12 (86%)	1 (7%)	13 (93%)	0.541

The RPE was not statistically different ($p = 0.458$; 95%CI = $-0.81 - 0.39$) between the PLA (16.73 ± 1.47) and CAP (16.95 ± 1.73) participants.

In the PEQ, when supplemented with capsaicin, two (2) individuals had a headache 15 minutes after training. Regarding intestinal discomfort, two (2) volunteers answered yes pre-session, but none answered yes at 15 min or 24 h after. As for muscle pain, nine (9) volunteers reported pain 15 minutes after and 11

answered yes 24 hours after the session. About tachycardia, insomnia and increased urine, no volunteer answered yes to the perception of these effects when supplemented with capsaicin. As for increased anxiety, one (1) volunteer answered yes pre-session and two (2) affirmed that they felt increased anxiety 24 hours after the end of the session. Also, three (3) volunteers reported increased vigour 15 min after the end of the session and one (1) reported this effect 24h

after the session. In all perceived effects, when compared with the responses provided by the placebo participants, the values did not show any significant differences. Table 1 reports the absolute values, percentages, and *p* values of the effects perceived by the volunteers in the placebo and capsaicin groups.

Discussion

The present study investigated the possible effect of capsaicin supplementation before a resistance training protocol, with multiple exercises and sets, in trained individuals. The occurrence of possible side effects was also investigated. The hypothesis was that supplementation would increase training performance without the perception of side effects. The results showed that capsaicin supplementation did not change the VL or NMR, which demonstrated that supplementation did not influence the training performance, in addition to not affecting the RPE. Also, the results showed that pre-workout supplementation did not change the perception of vigour and side effects.

Contrary to the results of the present study, Freitas et al. [4] found that the acute supplementation of 12 mg of capsaicin increased the NMR in 4 sets until muscle failure, with 70% 1RM in the Back Squat exercise. In another study, the same author found positive effects of capsaicin supplementation, with the same dose of 12 mg also on the NMR in the same exercise protocol, but being performed after an intermittent run of 5 km on a treadmill [8]. These authors suggest that such ergogenic effects are mainly due to increased calcium release in the sarcoplasmic reticulum during the resistance training. The differences between the results of these studies and those presented in the present study can be mainly attributed to differences in the training protocol adopted. In the present study, the volunteers performed a protocol of multiple exercises and sets, with two different exercises with five sets each. Thus, the greater volume performed in this study may have led the volunteers to a higher level of neuromuscular fatigue, and capsaicin may not produce a sufficient effect against this higher level of fatigue.

Similar to the present study results, Simões et al. [11] found no acute effects of supplementation of 12 mg of capsaicin on the VL in a training protocol for the lower body with 70% 1RM. In this study, the only exercise performed was the Back Squat, similar to the studies of Freitas et al. [4] and Freitas et al. [8]. This difference in the results suggests that the supplementation effect can be individual. Other studies with larger

samples need to be conducted to investigate this supplementation characteristic.

Protocols with multiple exercises and sets have been shown to be more effective in generating muscle hypertrophy in trained individuals [9]. Freitas et al. [4] suggest that the increase in training volume due to capsaicin supplementation can enhance the results of a training program for muscle hypertrophy. However, the results of the present study are contrary to this hypothesis, indicating that the supplementation of this substance as a pre-workout in resistance training does not improve performance in the session when it is composed of more than one exercise and, consequently, it may be ineffective in generating greater muscle hypertrophy in trained individuals.

On the other hand, Moura e Silva et al. [6] investigated the chronic effect of capsaicin supplementation over 6 weeks in untrained individuals and found an increase in fat-free mass for the upper body. However, such differences can be justified by the differences in the training level of the studied population and in the training protocol, considering that in the present study, the training protocol was directed at the lower body.

No other studies were found that investigated the effect of chronic capsaicin supplementation for muscle hypertrophy. This limits the discussion of the results of the present study and points to the need for further studies on the effects of capsaicin supplementation in resistance training, mainly aimed at muscle hypertrophy in trained individuals.

Regarding the RPE, no influence of capsaicin supplementation was found on this parameter in resistance training. These results are similar to Simões et al. [11], who also found no effect of this supplementation on the RPE in the adopted protocol. Similarly, Rossi et al. [17] also found no effects of supplementation with 12 mg of capsiate, a capsaicin analogue, on RPE in aerobic exercise at 70% of the maximum aerobic speed. Likewise, Freitas et al. [18] also did not find effects of acute capsaicin supplementation on RPE in high-intensity intermittent exercise on a treadmill. Contrary to these findings, in the study by Freitas et al. [4], acute supplementation with 12 mg of capsaicin reduced reported RPE values. Again, the differences between this study and the findings by Freitas et al. [4] can be justified by the greater volume of training performed in the present study, which may have led the volunteers to accumulated fatigue during training and, consequently, to similar averages of RPE between the experimental conditions. This still indicates that the volunteers per-

formed the sets close to their limits in both conditions, adjusting the NMR to the RPE, performing the training at maximum performance, as requested and aimed [13].

In the present study, the results also show that no increase in vigour was perceived by the volunteers due to capsaicin supplementation, which may be related to the ineffectiveness of this supplementation in reducing RPE and/or increasing performance in resistance training. So, the possible expected effects of greater CNS stimulation and greater tolerance to pain due to the decrease in sensitisation of nociceptors [19] are not corroborated by the results obtained in this study.

Capsaicin supplementation can generate some side effects, mainly gastrointestinal, possibly related to the individual tolerance and doses used [10]. In the present study, no side effects resulting from this supplementation were reported. These results agree with Freitas et al. [4], who state that volunteers did not report side effects resulting from acute supplementation with 12 mg of capsaicin. However, those authors did not investigate such possible side effects through specific tools or methods. Also, Simões et al. [11] reported a low incidence of side effects due to capsaicin supplementation (12 mg) in a resistance training protocol for lower body in trained individuals, using a specific questionnaire applied immediately after and 24 h after the training session.

Even though there is a lack of other studies to compare results, these findings are positive, considering that previous studies reported positive results in performance when a 12 mg dosage was adopted [4–8]. Therefore, this dose can be considered safe for supplementing this substance, and should be investigated in different individuals and populations, in addition to different training modalities and resistance training protocols.

It is important to note that tolerance to supplementation can be individual [10], along with its possible ergogenic effects [10–18]. In this scenario, given that at present an individual analysis of the volunteers was not performed, it is possible that adopting different doses, possibly relativised by body mass, would lead to different results.

In the present study, blood lactate concentrations were not evaluated. However, such an assessment may be unnecessary, considering that the influence of capsaicin supplementation on lactate concentrations was not verified in previous studies [4, 7, 8].

Conclusions

This was the first study to investigate the acute effect of capsaicin supplementation on a complete lower

body training session. Capsaicin pre-workout supplementation in resistance training has no perceived side effects, but it may not be effective at improving training performance in trained individuals.

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Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

References

1. Gonzalez AM, Pinzone AG, Bram J, Salisbury JL, Lee S, Mangine GT. Effect of multi-ingredient preworkout supplementation on repeated sprint performance in recreationally active men and women. *J Strength Cond Res.* 2020;34(4):918–923; doi: 10.1519/JSC.0000000000003480.
2. Salatto RW, Arevalo JA., Brown, LE., Wiersma, LD, Coburn, JW. Caffeine's effects on an upper-body resistance exercise workout. *J Strength Cond Res.* 2020;34(6):1643–1648; doi: 10.1519/JSC.0000000000002697.
3. Bergstrom HC, Byrd MT, Wallace BJ, Clasey JL. Examination of a multi-ingredient preworkout supplement on total volume of resistance exercise and subsequent strength and power performance. *J Strength Cond Res.* 2018;32(6):1479–14790; doi: 10.1519/JSC.00000000000002480.
4. Freitas MC, Cholewa JM, Freire RV, Carmo BA, Bontan J, Bratfich M et al. Acute capsaicin supplementation improves resistance training performance in trained men. *J Strength Cond Res.* 2018;32(8):2227–2232; doi: 10.1519/JSC.00000000000002109.
5. Arent SM, Walker AJ, Pellegrino JK, Sanders DJ, McFadden BA, Ziegenfuss TN et al. The combined effects of exercise, diet, and a multi-ingredient dietary sup-

- plement on body composition and adipokine changes in overweight adults. *J Am Coll Nutr.* 2018;37(2):111–120; doi: 10.1080/07315724.2017.1368039.
6. Moura e Silva VEL, Cholewa JM, Jäger R, Zanchi NE, Freitas MC, Moura RC et al. Chronic capsiate supplementation increases fat-free mass and upper body strength but not the inflammatory response to resistance exercise in young untrained men: A randomized, placebo-controlled and double-blind study. *J Int Soc Sports Nutr.* 2021;18(1):50; doi: 10.1186/s12970-021-00446-0.
 7. Freitas MC, Cholewa JM, Gobbo LA, Oliveira JV, Lira FS, Rossi FE. Acute capsaicin supplementation improves 1,500-m running time-trial performance and rate of perceived exertion in physically active adults. *J Strength Cond Res.* 2018;32(2):572–577; doi: 10.1519/JSC.00000000002329.
 8. Freitas MC, Cholewa JM, Panissa VLG, Toloi GG, Netto HC, Freitas CZ et al. Acute capsaicin supplementation improved resistance exercise performance performed after a high-intensity intermittent running in resistance-trained men. *J Strength Cond Res.* 2022; 36(1):130–134; doi: 10.1519/JSC.0000000000003431.
 9. Schoenfeld B, Grgic J. Evidence-based guidelines for resistance training volume to maximize muscle hypertrophy. *Strength Cond J.* 2018;40(4):107–112; doi: 10.1519/SSC.0000000000000363.
 10. Arnold JT, Stewart SB, Sammut L. Oral capsaicin ingestion: a brief update – dose, tolerance and side effects. *Res Rev J Herb Sci.* 2016;5(2):1–5.
 11. Simões CB, Gomes PLC, Silva RA, Fonseca I, Fonseca M, Cruz VM et al. Acute caffeine and capsaicin supplementation and performance in resistance training. *Motriz: Rev Educ Fis.* 2022; 28; doi: 10.1590/S1980-65742022010121.
 12. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. *British journal of nutrition.* 1978;40(3):497–504; doi: 10.1079/bjn19780152.
 13. Fonseca I, Cruz V, Fonseca M, Simoes C, Cossenzo P, Szmuchrowski LA et al. Subsequent Performance of Two 1RM Tests in the Same Session Reduces 1RM and Consequently the Volume Load of Strength Training Session. *J Exerc Physiol Online.* 2020;23(5).
 14. Drummond MD, Couto BP, Eufrasio RJ, Goncalves R, Smuchrowski LA. Energy balance in taekwondo athletes during pre-competition. *Arch Budo.* 2014;10:195–199.
 15. Wilk M, Krzysztofik M, Filip A, Zajac A, Del Coso J. The effects of high doses of caffeine on maximal strength and muscular endurance in athletes habituated to caffeine. *Nutrients.* 2019;11(8):1912; doi: 10.3390/nu11081912.
 16. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. *J Strength Cond Res.* 2004;18(4):918–920; doi: 10.1519/14403.1.
 17. Rossi PA, Lira FS, Bezerra VR, Clark NW, Fukuda DH, Panissa VLG. Acute response to capsiate supplementation at rest and during exercise on energy intake, appetite, metabolism, and autonomic function: a randomized trial. *J Am Nutr Assoc.* 2021;41(6):541–550; doi: 10.1080/07315724.2021.1938294.
 18. Freitas MC, Billaut F, Panissa VLG, Rossi FE, Figueiredo C, Caperuto EC et al. Capsaicin supplementation increases time to exhaustion in high-intensity intermittent exercise without modifying metabolic responses in physically active men. *Eur J Appl Physiol.* 2019; 119(4):971–979; doi: 10.1007/s00421-019-04086-w.
 19. Silva VEL, Cholewa JM, Billaut F, Jäger R, Freitas MC, Lira FS et al. Capsaicinoid and Capsinoids as an ergogenic aid: a systematic review and the potential mechanisms involved. *Int J Sports Physiol Perform.* 2021; 16(4):464–473; doi: 10.1123/ijsspp.2020-0677.