International Journal of EXERCISE SCIENCE

Original Research

Effect of a Commercially Available Low-Dose Capsaicin Supplement on Knee Extensor Contractile Function

BRETT L. CROSS*, DARELL PARKER†, SEAN P. LANGAN†, and GREGORY J. GROSICKI‡

Biodynamics and Human Performance Center, Georgia Southern University (Armstrong Campus), Savannah, GA, USA

*Denotes undergraduate student author, †Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 13(2): 312-318, 2020. Capsaicin, the active pungent ingredient in chili peppers and various spicy foods, is demonstrated to influence a variety of physiological systems including skeletal muscle. The purpose of this study was to examine if a chewable capsaicin supplement (1.2 mg) could enhance isokinetic knee extensor contractile performance. Nine young, recreationally active individuals (5 females/4 males; 23.6 ± 1.5 yrs; 24.2 ± 3.3 kg/m^2) participated in this randomized, single-blind crossover study. Following a familiarization session, participants completed two isokinetic knee extensor contractile function assessments, 45 minutes after ingesting either a capsaicin fruit gummy or eucaloric placebo, the order of which was randomized. Knee extensor peak torque (strength), summed torque (endurance) and fatigue index (fatigue) were compared between trials. Knee extensor peak torque was significantly greater ($p < 0.05$; $d = 0.80$) in the capsaicin (126.0 ± 40.4 N·m^{-1}) than the placebo (118.8 ± 41.3 N·m^{-1}) trial. No significant differences ($p > 0.05$) were found for summed torque (8012 ± 2771 vs. 7823 ± 2611 N·m^{-1}; $d = 0.45$) or fatigue index (56.0 ± 17.1 vs. 48.7 ± 21.0 %; $d = 0.46$) between capsaicin and placebo trials, respectively. These findings, in a relatively modest and mixed-gender sample, suggest that pre-exercise capsaicin ingestion may benefit knee extensor muscle strength but does not appear to affect parameters of skeletal muscle endurance or fatigue.

KEY WORDS: Skeletal muscle, nutrition, ergogenic aid

INTRODUCTION

Capsaicin (8-methyl-N-vanillyl-trans-6-nonenamide), the pungent ingredient in chili peppers, has recently been explored by a number of physiological studies due to its unique ability to influence an array of bodily systems. The physiological implications of capsaicin are mediated by its binding to transient receptor potential vanilloid receptor-1 (TRPV1) ion channels found primarily in the peripheral and central nervous systems (16). Functional expression of TRPV1 on the sarcoplasmic reticulum of skeletal muscle has also been observed where it is suggested to participate in intracellular calcium regulation (13). Capsaicin-mediated TRPV1 activation in

skeletal muscle may potentiate calcium release in a manner that modifies myofilament interaction and ultimately intensifies force production.

In animal models, capsaicin doses more substantial than can be safely tolerated in human subjects have proven to increase both strength (10) and endurance (14). More modest capsaicin doses in human studies have yielded equivocal results (4-6, 12, 17), and may still evoke gastrointestinal distress (17). To overcome possible gastrointestinal complications, oral stimulation of TRPV1 in the oropharynx has been suggested (8, 12). The present study sought to evaluate the effect of a commercially available, chewable, low-dose (1.2 mg) capsaicin supplement on contractile performance of the knee extensors in recreationally active individuals. Notably, previous findings from our laboratory in a cohort of 13 young, recreationally-active individuals demonstrated that this dose was well-tolerated, although no improvements in endurance cycling performance were observed (12). Using a novel isokinetic knee extensor testing protocol (2, 7), we evaluated the potential for capsaicin to improve multiple domains of skeletal muscle function including peak torque (strength), summed torque (endurance) and fatigue index (fatigue). Based on previous findings demonstrating capsaicin-mediated enhancements in total mass lifted (i.e., endurance) when performing squat sets to failure (4), we hypothesized that acute capsaicin ingestion would improve both muscular endurance and fatigue. To our knowledge, this was the first study to evaluate whether capsaicin may enhance maximal force production in human subjects.

METHODS

Participants

Nine young (18-30 yrs), recreationally active (≥ 30-min self-reported moderate-vigorous physical activity ≥ 3-d per week for ≥ 3 months) males and females were recruited to participate in this single-blind, randomized crossover study, consisting of three total visits. All participants were deemed fit for maximal exercise participation by means of the Physical Activity Readiness Questionnaire (PAR-Q+) and a pre-participation health screening questionnaire, per the guidelines of the American College of Sports Medicine (1). Participants with pre-existing orthopedic or neurologic conditions, or those reporting allergies to any ingredients in the capsaicin supplement were excluded. Prior to providing their consent to participate, all participants were verbally informed of the risks, procedures, and goals of the study. This study was approved by the Georgia Southern University Institutional Review Board and all subjects provided written informed consent to participate. Research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (15).

Protocol

On the day of the first study visit, participants reported to the laboratory and height and body mass were obtained on a wall-mounted stadiometer and calibrated digital scale, respectively. Body fat percentage was then assessed via bioelectrical impedance analysis using an Omron HBF-306CN portable device (Omron Healthcare, Osaka, Japan) (18) prior to familiarization with the isokinetic knee extensor performance test. The isokinetic knee extensor contractile function test was performed on a Biodex System 3 dynamometer (Biodex Medical Systems, Shirley, NY)

and consisted of 120 maximal isokinetic knee extensions at 120° per second with passive flexion at 240° per second, as previously described (2, 7). This assessment protocol has been demonstrated to exhibit excellent test-retest reliability for evaluation of knee extensor strength, endurance and fatigue by our laboratory in a similar population (3). Prior to departure, subjects were scheduled for their second and third study visits, which were at least 72 hours but no more than 14 days apart.

The day prior to the second and third study visits participants were asked to avoid spicy food and to refrain from vigorous physical activity. They were also asked to follow similar dietary patterns for the 24 hours preceding the study visits, which was verified by completion of a dietary log in which participants were asked to document all food and drink, besides water, consumed. Upon arrival to the testing facility, participants consumed either a 1) spicy fruit gummy (139 kcals) containing 1.2 mg capsaicin (Bollox Ltd, Admirality, Hong Kong) or 2) eucaloric placebo, the order of which was randomized. For the next 45 minutes subjects were asked to sit quietly without audio/visual stimulation. Consumption of food or drink, excluding water, was prohibited between the time of supplement consumption and the start of testing. After the waiting period, participants were brought to the dynamometer for completion of the isokinetic knee extensor contractile function assessment. The test lasted approximately 4 minutes in duration and standardized verbal encouragement was provided throughout the test by the research team. Prior to departure, subjects were given a gastrointestinal distress form where they were asked to document any unusual symptoms occurring over the next 48 hours. Second and third study visits were conducted at roughly the same time of day (± 2 hours) for chronobiological control.

A detailed description of variables obtained from the isokinetic knee extensor fatigue test has been previously described (2, 7). Skeletal muscle strength was quantified as peak torque, which was defined as the greatest amount of torque produced within a 10-millisecond increment over the course of the test. Muscle endurance was quantified as summed torque, a composite index of strength and fatigue, calculated by summing the peak torque for each of the 120 repetitions (9). Finally, fatigue index, was expressed as a percent and calculated by subtracting the mean torque from the first five contractions from the mean torque of the last five contractions, divided by the torque from the first five contractions. In this manner, performance at the end of the test is compared to initial torque, with a higher value indicating greater fatigue development and a value of 0 indicating no fatigue has occurred.

Statistical Analysis

Data was analyzed using SPSS, version 25.0 (SPSS Inc, Chicago, IL, USA). Normality was verified using the Shapiro-Wilk test. Inter-trial comparisons of peak torque, summed torque, and fatigue index were conducted using a paired samples t-test. Statistical significance was set at $p < 0.05$. The effect size was calculated using Cohen's d, and whereby a value of 0.20 was considered small, 0.50 moderate, and 0.80 large.

RESULTS

Participant characteristics are provided in Table 1 as means ± SD. The capsaicin supplement was well-tolerated by all participants, without a single complaint of gastrointestinal distress.

Table 1. Subject characteristics (Means ± SD).

	Age (yrs)	Height (cm)	Weight (kg)	BMI (kg/m²)	Body Fat (%)
Males (*n* = 4)	25.3 ± 3.1	179.9 ± 3.6	86.5 ± 9.7	27.0 ± 2.6	17.0 ± 3.7
Females (*n* = 5)	22.3 ± 2.1	162 ± 9.0	68.0 ± 8.5	26.2 ± 1.0	27.0 ± 2.7

Contractile Function: Peak torque production was significantly greater (p = 0.04; d = 0.80) following the capsaicin (126.0 ± 40.4 N·m^{-1}) versus placebo (118.8 ± 41.3 N·m^{-1}) supplement, a finding that was observed in 6 of our 9 subjects (Figure 1). Exploratory analyses revealed a lack of significant gender (2 females/1 male) or anthropometric differences (p > 0.05) between the three individuals in whom a lack of benefit was noted and the six in whom strength was improved. No significant differences (p > 0.05) in summed torque (8012 ± 2771 vs. 7823 ± 2611 N·m^{-1}; d = 0.45) or fatigue index (56.0 ± 17.1 vs. 48.7 ± 21.0 %; d = 0.46) were observed between capsaicin and placebo trials, respectively. Between trial changes in measures of contractile function did not appear to be influenced by gender and no order effects were observed.

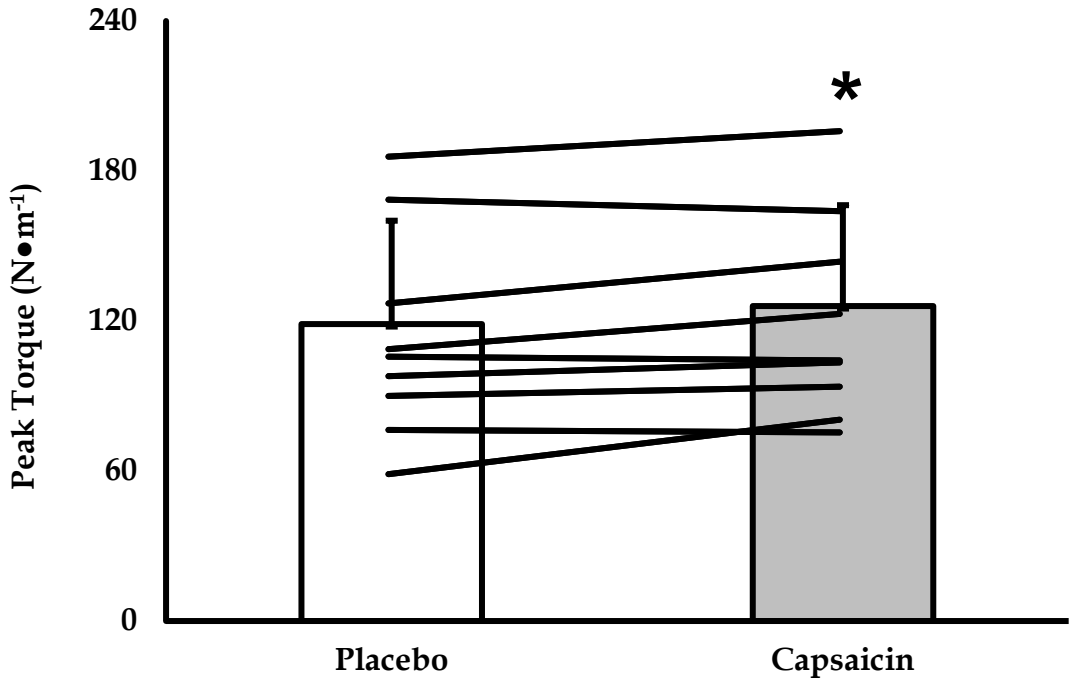

Figure 1. Means ± SD (bars) and individual data points (lines) for placebo and capsaicin peak torque trials.

DISCUSSION

We explored the effects of a commercially available, chewable, low-dose (1.2 mg) capsaicin supplement on isokinetic knee extensor contractile performance. Lower-extremity peak torque (i.e., muscle strength) was ~6% greater following the capsaicin trial. Pertinently, the administered capsaicin dose (1.2 mg) was well-tolerated by all participants, offering confidence to athletes and practitioners debating the pros and cons of low-dose pre-exercise capsaicin ingestion. However, contrary to our hypothesis the capsaicin supplement failed to provide any appreciable benefit for measures of muscular endurance or fatigue.

To our knowledge, this was the first study to demonstrate the potential for acute capsaicin supplementation to enhance skeletal muscle strength in humans. In mice, 4 weeks of capsaicin administration was similarly demonstrated to improve grip strength concomitant with enhancements in endurance capacity (i.e., swim time) (10). Human studies using larger capsaicin doses in pill form have also observed acute enhancements in muscular endurance (4-6), quantified during both aerobic (i.e., 1500-m run time) and resistance (i.e., squat sets to failure) exercise. The apparent lack of ergogenic benefit for measures of muscular endurance and fatigue observed in the present study may be attributed to the very low-dose of capsaicin administered, which was likely insufficient to provide any significant modulation of bioenergetics (14, 19). Nonetheless, a similar low capsaicin dose (2.56 mg) has proven to influence substrate metabolism (i.e., enhance fat oxidation), albeit in subjects following a hypocaloric diet (11).

A limitation of the present investigation is a lack of ability to delineate the mechanisms underlying the acute increase in force production following capsaicin administration. Though transient modulation of calcium kinetics (13) or upregulations of autonomic nervous system activity (19) may have contributed, the placebo effect should not be dismissed. Indeed, placebo administration is demonstrated to augment isokinetic knee extensor muscle force production by a comparable (~10%) extent (20). To avoid exacerbating this issue, we refrained from asking the participants whether they could differentiate between treatments, but were told by many that the capsaicin supplement was notably pungent. While this is an obvious limitation of the present study, if an understanding of whether oral TRPV1 stimulation may potentiate the ergogenic benefits of capsaicin is desired, this obstacle is difficult to overcome. It is worthy to note that previous research by our laboratory using the same chewable capsaicin dose reported a lack of benefit for time-to-exhaustion during cycling exercise (12), although these inter-study differences may simply be a product of highly discrepant exercise modalities rather than a lack of placebo effect, per se.

In summary, acute ingestion of a low-dose (1.2 mg), chewable, capsaicin supplement significantly improved knee extensor force production, but did not affect measures of muscular endurance of fatigue. Importantly, no cases of gastrointestinal distress were reported following ingestion of the capsaicin supplement. These findings in a relatively modest and mixed-gender sample suggest that tolerable quantities of capsaicin ingested prior to exercise may be of benefit for individuals seeking to enhance lower-extremity muscle strength. However, conformation of

this apparent capsaicin-mediated acute enhancement in skeletal muscle force production in a larger sample is warranted prior to making any definitive claims.

REFERENCES

1. American College of Sports Medicine. ACSM's Guidelines for Exercise and Prescription 10th ed. Philadelphia: Wolters Kluwer; 2018.

2. Callahan DM, Foulis SA, Kent-Braun JA. Age-related fatigue resistance in the knee extensor muscles is specific to contraction mode. Muscle Nerve 39: 692-702, 2009.

3. Creque Z, Carreker J, Parker D, Riemann B, Grosicki GJ. Test-retest reliability of a novel isokinetic knee extensor fatigue test in young adults. In: National Strength and Conditioning Association 2019 National Conference Proceedings. Washington, D.C.; 2019.

4. de Freitas M, Freire RV, Carmo BA, Bottan J, Bratfich M, Della Bandeira MP, Goncalves DC, Caperuto EC, Lira FS, Rossi FE. Acute capsaicin supplementation improves resistance training performance in trained men. J Strength Cond Res 32: 2227-2232, 2018.

5. de Freitas MC, Billaut F, Panissa VLG, Rossi FE, Figueiredo C, Caperuto EC, Lira FS. Capsaicin supplementation increases time to exhaustion in high-intensity intermittent exercise without modifying metabolic responses in physically active men. Eur J Appl Physiol 119: 971-979, 2019.

6. de Freitas MC, Cholewa JM, Gobbo LA, de Oliveira J, 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 32: 572-577, 2018.

7. Englund DA, Price LL, Grosicki GJ, Iwai M, Kashiwa M, Liu C, Reid KF, Fielding RA. Progressive resistance training improves torque capacity and strength in mobility-limited older adults. J Gerontol A Biol Sci Med Sci 74: 1316-1321, 2019.

8. Gibson OR, Wrightson JG, Hayes M. Intermittent sprint performance in the heat is not altered by augmenting thermal perception via L-menthol or capsaicin mouth rinses. Eur J Appl Physiol 119: 653-664, 2019.

9. Grosicki GJ, Englund DA, Price L, Iwai M, Kashiwa M, Reid KF, Fielding RA. Lower-extremity torque capacity and physical function in mobility-limited older adults. J Nutr Health Aging 23: 703-709, 2019.

10. Hsu YJ, Huang WC, Chiu CC, Liu YL, Chiu WC, Chiu CH, Chiu YS, Huang CC. Capsaicin supplementation reduces physical fatigue and improves exercise performance in mice. Nutrients 8: 2016.

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

12. Langan S, Grosicki GJ. Commercially available capsaicin supplement fails to enhance time-to-exhaustion during cycling. Int J Exerc Sci 13: 225-233, 2020.

13. Lotteau S, Ducreux S, Romestaing C, Legrand C, Van Coppenolle F. Characterization of functional TRPV1 channels in the sarcoplasmic reticulum of mouse skeletal muscle. PLoS One 8: e58673, 2013.

14. Luo Z, Ma L, Zhao Z, He H, Yang D, Feng X, Ma S, Chen X, Zhu T, Cao T, Liu D, Nilius B, Huang Y, Yan Z, Zhu Z. TRPV1 activation improves exercise endurance and energy metabolism through PGC-1alpha upregulation in mice. Cell Res 22: 551-564, 2012.

15. Navalta J, Stone W, Lyons S. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12: 2019.

16. O'Neill J, Brock C, Olesen AE, Andresen T, Nilsson M, Dickenson AH. Unravelling the mystery of capsaicin: a tool to understand and treat pain. Pharmacol Rev 64: 939-971, 2012.

17. Opheim MN, Rankin JW. Effect of capsaicin supplementation on repeated sprinting performance. J Strength Cond Res 26: 319-326, 2012.

18. Pribyl M, Smith J, Grimes G. Accuracy of the Omron HBF-500 body composition monitor in male and female college students. Int J Exerc Sci 4: 93-101, 2011.

19. Shin KO, Moritani T. Alterations of autonomic nervous activity and energy metabolism by capsaicin ingestion during aerobic exercise in healthy men. J Nutr Sci Vitaminol (Tokyo) 53: 124-132, 2007.

20. Tallis J, Muhammad B, Islam M, Duncan MJ. Placebo effects of caffeine on maximal voluntary concentric force of the knee flexors and extensors. Muscle Nerve 54: 479-486, 2016.