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Acute Capsaicin Supplementation may not Be Effective in Improving the Physical and Cognitive Performance of Taekwondo Athletes and Para Athletes

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SUMMARY

Purpose. The present study aimed to investigate the acute effect of capsaicin supplementation on Taekwondo performance.

Methods. This was a crossover, double-blind, placebo-controlled study that evaluated 13 Taekwondo athletes (24.8 ± 10.6 years; 64.5 ± 10.9 kg; 171 ± 9.16 cm), male (n = 10) and female (n = 3), athletes (n = 8) and para athletes (n = 5). The volunteers performed two experimental supplementation conditions: capsaicin (CAP) (12 mg) or Placebo (PLA). Performance evaluation included the frequency of kick test multiple series (FSKTmult), countermovement jump (CMJ), and Stroop test. The relative perception effort during the tests (RPEtest) and after the sessions (RPEsession), as well as capillary lactate concentration and blood glucose, were also recorded.

Results. No significant differences were found between the experimental conditions in the FSKTmult test (CAP: 265.46 ± 21.85; PLA: 262.31 ± 22.96; p = 0.413); CMJ (CAP: 37.25 ± 10.31cm; PLA: 36.97 ± 10.86 cm; p = 0.761), and Stroop Test (Stroop test 1: CAP: 978.73 ± 185.43 ms; PLA: 950.02 ± 174.82 ms; Stroop test 2: CAP: 881.16 ± 212.74 ms; PLA: 813.75 ± 155.04 ms; p = 0.490). No significant differences were also found between the experimental conditions in the results of the RPEtest, RPEsession, lactate concentration, and blood glucose (p > 0.05).

Conclusions. Acute capsaicin supplementation may not be effective in improving the physical and cognitive performance of Taekwondo athletes and para athletes.

KEY WORDS

Ergogenic aids; nutrition; martial arts; TRPV cation channels; sports.

INTRODUCTION

Capsaicin, a substance found in peppers, may be effective in enhancing physical performance, particularly related to strength resistance and reducing perceived exertion (1, 2). In humans, there is evidence that capsaicin can improve performance in running (3, 4,) resistance training (5, 6), concurrent training protocols (7), and CrossFit (8). Da Silva *et al.* (9) reported that capsaicin increased power

performance of Jiujitsu athletes in the bench press exercise. Thornton *et al.* (10) suggest that capsaicin supplementation may enhance cognitive function.

The primary mechanism of action of capsaicin is through the activation of the transient receptor potential vanilloid 1 (TRPV1), present in the sarcoplasmic reticulum of skeletal muscles (11), in the central nervous system, in myelinated nerve fibers, and non-myelinated nociceptors (1, 12). The potential ergogenic effect of capsaicin is thought to occur via increased and sustained release of calcium ions ($Ca2^{+}$) by the sarcoplasmic reticulum, thereby sustaining muscle contraction for a longer period and enhancing strength resistance (5, 6). Furthermore, capsaicin may increase pain and discomfort thresholds, leading to a reduction in perceived exertion (2, 5), mainly through the saturation of capsaicin-sensitive afferent neurons, which can induce a desensitization response of nociceptors (1). Additionally, by activating TRPV1 receptors in the central nervous system (CNS), capsaicin may trigger the release of neurotransmitters in the prefrontal cortex, which can directly influence cognitive performance and improve decision-making (13).

Taekwondo is a sport characterized by intermittent demands that must be sustained for several minutes during training sessions and competitions (14). Therefore, optimal development of various physical aptitudes is required for competitive success, particularly related to overall endurance, strength, and the ability to react to stimuli and make decisions (15, 16). Given the potential positive effects of capsaicin supplementation to increase strength resistance, reduce perceived exertion (1), and potentially influence cognitive aspects (13), Taekwondo athletes may benefit from this ergogenic aid in training and competition. Therefore, the present study aimed to investigate the acute effect of capsaicin supplementation on Taekwondo performance We hypothesized that capsaicin would enhance physical and cognitive performance in Taekwondo.

METHODS

Study design

This was a crossover, double-blind, placebo-controlled study. Data were collected over four experimental sessions, which took place during a period of three weeks. Familiarization was conducted in two sessions during the first week. In the subsequent two weeks, the experimental sessions were carried out with a one-week interval between them. Volunteers were instructed not to engage in physical activity or strenuous exercise twenty-four hours before the experimental sessions to ensure recovery and minimize the interference of weekly training loads on test results.

In the first experimental session, sample characterization and familiarization with the Stroop test (17) were conducted. Additionally, 48 hours after the initial familiarization session, the Stroop Test protocol was repeated to assess the reliability of this measure. Sample characterization included recording body mass, body fat percentage, height, and a 24-hour dietary recall. In the subsequent experimental sessions, supplementation protocols and performance tests were conducted, with volunteers consuming either capsaicin (CAP) or placebo (PLA). The distribution of participants was counterbalanced, with the order of treatments randomly assigned.

The tests performed were Frequency Speed of Kick Test Multiple series (FSKTmult), countermovement jump (CMJ) (18), and the Stroop test (19). At the beginning of the supplementation and performance test sessions, data from the perceived recovery scale (PRS) were collected to assess the volunteers' recovery status (20). Additionally, capillary serum lactate and glucose concentration were recorded before (pre-test) and after (post-test) the sessions.

To minimize potential influences of variations in participants' diet, dietary recalls were conducted before each experimental session. Volunteers were instructed to maintain their usual dietary patterns throughout the study and replicate the meal before each experimental session. If the intake of macronutrients (carbohydrates, lipids, proteins) and energy showed a variation of 5% or more, positive or negative, between sessions, the volunteer would be excluded. No volunteer was excluded. Nutritional analysis was performed using the DietBox® application (version 6.8.3, Brazil) (21).

Participants

Thirteen Taekwondo athletes (n = 8) and para athletes (n = 5) (24.8 ± 10.6 years old, 64.5 ± 10.9 kg; 171 ± 9.16 cm) of both sexes (males n = 10; females n = 3) participated in the study. The para athletes were classified into the K44 competitive category (athletes with unilateral amputation from the knee to the hand joint, unilateral dysmelia, monoplegia, hemiplegia light and size difference in the lower limbs) (22). All participants were black belts and experienced in international competitions.

The sample size was defined a priori based on the study by Freitas *et al.*, (5), the effect size of 0.84 was adopted, referring to the effect of capsaicin supplementation on the strength resistance (total volume). A power of 0.8 and alpha of 0.05 were considered. Using the Gpower software (version 3.1), a sample size of 13 volunteers was obtained. Participants were recruited through the promotion of the

research in Taekwondo training centers, research institutions, and social media platforms.

The inclusion criteria were as follows: not being a smoker or allergic to pepper, being a Taekwondo athlete of at least 14 years old, not having experienced any type of joint and/or muscle injury in the lower limbs in the six months prior to the start of the study, not being users of nutritional and pharmacological ergogenic aids, and not presenting a potential health risk after responding the Physical Activity Readiness Questionnaire (PAR-Q). Volunteers would be excluded if they incurred injuries during the study or had any conditions that could interfere with the testing protocol. No participants were excluded from the present study.

Ethical care

All procedures and the purpose of the study were explained to the volunteers, as well as the possible risks and benefits. This research complied with the legislation of the National Health Council - Brazil (Res 466/2012). The present study was approved by the Ethics and Research Committee of the Federal University of Minas Gerais (protocol number: 5.765.153 – date of approval: November 19, 2022). All participants signed the informed consent form.

Procedures

The protocols of the familiarization with the countermovement jump (CMJ) and FSKTmult tests were the same as those adopted by Silva *et al.* (18). In the Stroop Test familiarization sessions, volunteers performed the test six times, to minimize the learning effect. After the familiarization sessions, the results obtained in the first and second sessions of each test were compared. If there was a significant difference, a third session would be held 48 hours later. It was not necessary to perform an additional familiarization session. Performance in the tests of the two sessions was used to determine the intraclass correlation coefficient (ICC) and the Standard Error of Measurement (SEM) (23).

Capsaicin (Manipulatta Compounding Pharmacy, Brazil) supplementation dose was 12 mg, as it was the same dose adopted in studies that identified the effectiveness of this substance in improving performance (3-5, 7), without occurrences of side effects (21). The Placebo capsule contained 50 mg of starch, being identical to the Capsaicin capsules. The distribution of volunteers was random by draw, but it was ensured that the number of participants in both situations was the same. The capsules were ingested 45 minutes before the experimental session, as capsaicin has its peak concentration after this time, when ingested (1,7).

The FSKTmult test was adopted in the present study as a specific physical test for Taekwondo (18, 24, 25) To maximize the similarity of the study protocol with actual combats, three rounds of FSKTmult were conducted, with a one-minute interval between each round. The protocol was the same as that adopted by Silva *et al.* (18). The variables analyzed included the number of kicks applied in each series, the total number of kicks, and the fatigue index. The fatigue index was calculated using the following equation (26): *Fatigue index (%) = 1 - [(FSKTmult total kicks) / (best FSKT × number of sets)] × 100*.

The FSKTmult tests were filmed, and the Kinovea video analysis software (Kinovea® version 0.8.15) was used to count the number of kicks. The counting started when the athlete initiated the attacking foot movement and ended when they contacted the Boomboxe® (26). Only kicks that reached the target within 10 seconds were considered valid (kicks that started within 10 seconds but contacted the Boomboxe® after 10 seconds were not counted) (26).

The CMJ was adopted as a test of general physical performance (18). The data analyzed from the CMJ test included the variables of jump height, maximum relative power, and mean relative power (W/kg) (27). The CMJ technique in the present study was the same as that adopted by Silva *et al.* (18).

The Stroop Test was adopted in the present study as a general cognitive test to observe the effect of executive function and its usefulness was to measure the response time to a visual stimulus (reaction time) (17). The test presents a non-sequential series of color names printed in different colors (yellow, white, red and orange, on a black background). It evaluates the level of color interference, since the volunteer must name the color of the font instead of reading the written color name, which will always be incongruous. This test comprises 25 stimuli. This test was presented to the athletes on a notebook, programmed in HTML format (28), and was carried out between the FSKTmult series, with the test carried out between the first and second series of the FSKTmult being classified as Stroop test 1. FSKTmult, and Stroop test 2 between the second and third series of FSKTmult. Each Stroop Test battery lasted 50 seconds. In this test, only the time taken to react to the visual stimulus was calculated (18, 29).

The relative perception of effort (RPE) was recorded using the Borg Scale (30), modified by Foster *et al.* (31). RPE was recorded immediately after the end of each round of the FSKTmult (RPEtest) (32). The RPE in relation to the entire session (RPEsession) was recorded 30 minutes after the completion of the three rounds of the FSKTmult. Each athlete reported a value on the scale, related to the effort perceived in the training session (18). This measure allowed recording the general perception of effort relative to the test

session in its entirety, being determined at rest, as a form of recall. This can minimize biases in identifying the level of effort immediately after completing the task, which can be influenced by discomfort and momentary fatigue. The RPEsession was calculated based on the equation by Foster *et al.* (31) (*RPEsession = RPE (CR-10) × training duration (minutes)*).

Due to the possible metabolic changes caused by ingesting capsaicin (2, 5), a comparison was made between the blood lactate and blood glucose concentrations, pre- and post-test (24, 33). Before the experimental supplementation and testing sessions, volunteers remained at rest for 10 minutes so that capillary blood glucose levels and pre-test serum lactate concentrations could be collected. At the end of the FSKTmult (after the 3rd round), after an interval of approximately one minute the blood glucose and post-test serum lactate concentration were measured. Such procedures were the same as those adopted by Silva *et al.* (18). To performance these procedures, were used a FreeStyle Optium Neo glucometer (Abbott Laboratórios do Brasil Ltda) and an Accutrend Plus lactimeter (Roche Diagnostics Ltda, Brazil).

The Perceived Recovery Scale (PRS) was proposed to monitor the recovery status of athletes (20). In this tool, the athlete indicates what their recovery status is in relation to the previous training session. The evaluator instructed the participant to choose a descriptor and then a number from 0 to 10. The maximum value (10) must be compared to fully recovered and the minimum value (0) is the not recovered condition (18).

Statistical analysis

Data normality was checked using the Shapiro-Wilk test. To verify the stabilization of Stroop test performance, in the familiarization sessions, a paired student test was used. To verify the relative reliability of the Stroop test, the two-way mixed intraclass surface coefficient was used. A paired student t-test or Wilcoxon test (when data is not normally distributed) were used to compare the number of total kicks, jump height, mean relative power, maximum power, PRS between treatments. Two-way ANOVA for repeated measures analyzing fixed factors (Treatment and Time) was used to analyze the results on the number of kicks per round, fatigue index, Stroop test, RPE, blood glucose and lactate, under the proposed experimental conditions. Bonferroni post-hoc was used to identify where differences exist, when necessary. To compare the means of the dietary profile at the beginning and end of the experimental intervention, the paired student t-test was used. For all statistical analyses was adopted $p < 0.05$. For all variables, the effect size was evaluated using Cohen's d, which presents the classifications small (0.2-0.3), medium (0.5-0.8) and large (greater than 0.8) (34). The JAMOVI software (version 2.3.26) was used for statistical analyses and the GraphPad Prism software (version 9.5.1) was used to produce the graphs. A descriptive analysis of the data was also carried out.

RESULTS

Lactate concentration, jump height, maximum power, mean power, fatigue index of the adapted FSKTmult, Stroop Test and RPEsession showed normal data distribution. PRS, RPEtest; blood glucose, and the mean total number of kicks in the FSKT showed a non-normal distribution.

No significant differences between treatments were shown for the total number of kicks (CAP: 265.46 ± 21.85; PLA: 262.31 ± 22.96; 95%CI -11.27, 4.964; SEM: 3.725; p = 0.1833; d = 0.14; **figure 1A**). Also, no significant difference was identified in the number of kicks applied in each round, when comparing CAP (FSKT1: 91.08 ± 9.85; FSKT2: 87.54 ± 7.38; FSKT3: 86.85 ± 5.67) and PLA (FSKT1: 91.00 ± 8.78; FSKT2: 86.46 ± 7.90; FSKT3: 84.85 ± 7.54) (95%CI -4.996, 7.099; SEM: 2.930; p = 0.99; d = 0.129). However, in the PLA

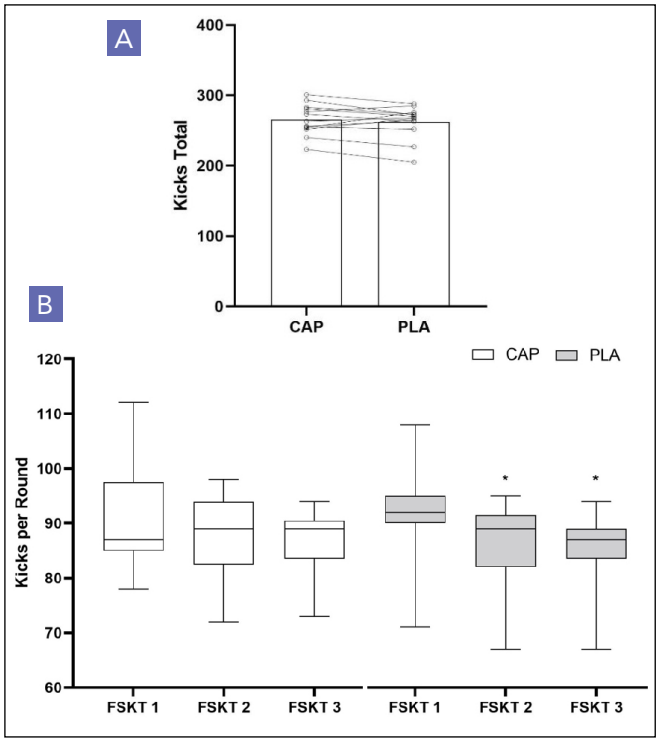

Figure 1. Frequency speed of kick test multiple series for CAP and PLA.

CAP: capsaicin; PLA: Placebo; FSKTmult: Frequency speed of kick test multiple series; *significant difference compare with FSKT1.

condition the number of kicks performed in the FSKT1 was significantly greater than that performed in the FSKT2 (p = 0.017) and FSKT3 (p = 0.0032) (**figure 1B**). There was no significant difference between the Fatigue Index values for the CAP (7.623 ± 4.015%) and PLA (7.704 ± 3.969%) conditions (95%CI -2.457, 2.295; SEM = 1.151; p = 0.99; d = 0.02). When analyzing jump height, maximum relative power, mean relative power, and Stroop test, no significant differences were found between the experimental conditions. However, in comparison between Stroop Test 1 and Stroop Test 2, there was a significant difference in both experimental conditions (95%CI 72.90, 160.90; p = 0.0001; d = 0.25). Additionally, there was no significant difference in PRS, RPE, RPE session, and lactate concentrations. Regarding blood glucose, the pre-test and post-test moments also did not show a significant difference between CAP and PLA. However, when analyzing the time factor, there was a significant difference, with higher blood glucose values reported for the PLA condition when comparing the pre-test and post-test moments (p = 0.013; d = -0.21). **Table I** shows these results.

DISCUSSION

The present study aimed to investigate the possible acute effects of capsaicin supplementation on the performance of Taekwondo athletes and para athletes. The results showed there was no significant difference between the experimental conditions, when comparing the physical and cognitive performance variables. Therefore, the results of this study refute the hypothesis that capsaicin could acutely increase performance in Taekwondo.

The variables analyzed in the specific FSKTmult test (number of total kicks, number of kicks per block and fatigue index) showed no difference, with a trivial effect size in all of them. These findings are similar to other studies, which also did not find an increase in physical performance with acute capsaicin supplementation (8, 9, 21, 35-37). However, other studies concluded that acute capsaicin supplementation was effective in improving performance in 400 m, 1,500 m and 3,000 m running (3, 4), and strength performance (5, 38). The positive effects of capsaicin supplementation are attributed to the possible increase in Ca^{2+} concentration

Table I. Mechanical and psychobiological variables.

	CAP	PLA	95%CI	P-value	Cohen d
Jump Height(cm)	37.25 ± 10.31	36.97 ± 10.86	-0.436, 0.655	0.347	0.11
Max Power(W/kg)	23.83 ± 6.35	23.68 ± 6.70	-0.396, 0.698	0.295	0.15
Med Power(W/kg)	10.55 ± 3.45	10.55 ± 3.59	-0.497, 0.590	0.433	0.04
Stroop 1(m/s)	978.73 ± 185.43	950.02 ± 174.82	-93.56, 189.7	0.490	0.30
Stroop 2(m/s)	881.16 ± 212.74	813.75 ± 155.04			
RPEsession	155 ± 52.4	154 ± 62.6	-21.4, 24.8	0.876	0.04
RPEtest	6.54 ± 2.48	6.54 ± 2.52	-1.94, 1,94	0.999	0.00
LAC			-1.308, 2.054	0.979	0.07
LAC pre(mmol/L)	2.25 ± 0.93	1.90 ± 0.55			
LAC post(mmol/L)	10.32 ± 3.73	9.92 ± 4.09			
BG			10.15, 7.92	0.995	0.11
BG pre	98.62 ± 11.77	96.77 ± 7.38			
BG post	109.62 ± 21.29	113.69 ± 16.70			
PRS	7.38 ± 2.26	8.00 ± 1.78	-3.00, 5.80	0.152	-0.56

CAP: capsaicin; PLA: placebo; Max Power: maximum relative power; Med Power: mean relative power; RPE: Rate of Perceived Exertion; LAC: lactate concentration; BG: blood glucose; PRS: perceived recovery scale.

in the sarcoplasm and the possible analgesic effect of this substance (1, 2, 5).

However, the possible positive effects expected from acute capsaicin supplementation were not effective in improving Taekwondo performance, suggesting a specificity of the response in relation to the demand characteristic. No other studies were found that investigated capsaicin supplementation in Tekwondo or that compared the effectiveness in different modalities, which indicates the need for studies with these objectives. Also, Simões *et al.* (21) suggest that the response to supplementation is individual (39, 40) and for trained individuals, a higher dosage of the supplement is necessary. Other studies with animals indicated that the effect of capsaicin may be dose dependent (41-43). Therefore, studies with humans are needed to investigate and compare different doses of acute capsaicin supplementation, especially with doses related to the individuals' body mass.

The results of the present study showed no differences in the variables analyzed in CMJ, indicating that capsaicin supplementation was not effective in improving general physical performance. However, the literature presents evidence contrary to the present study. Da Silva *et al.* (9) investigated acute capsaicin supplementation in Jiujtsu fighters, when performing the bench press exercise, using the same dosage as in the present study (12 mg). The results show an increase in power production, one of the variables analyzed in the present study, through the CMJ. The authors hypothesized that the effectiveness of capsaicin to increase power was due to a possible sympathetic modulation that causes the release of acetylcholine in the presynaptic cleft (1). In the present study, volunteers performed CMJ, an exercise that also assesses power and uses the ATP and phosphocreatine (PCr) systems primarily, and no evidence was found that corroborates the study by Silva *et al.* (9). Once again, a possible explanation for the difference in study results would be individual variation in response to supplementation (21, 39, 40).

Regarding the Stroop test, acute Capsaicin supplementation did not influence the results, contrary to Thornton *et al.* (10), who state that capsaicin can improve functions associated with cerebrovascular function and cognition. In the results of the present study, differences were identified between the Stroop test 1 and the Stroop test 2, in both experimental conditions. This result can be justified by the inverted U theory (44). Once the ability of exercise to stimulate cognition and increase the focus of attention is understood (44), this attention may have been raised to an optimal state of activation, allowing an increase in performance when comparing the two tests. Some studies obtained positive responses in executive function through acute Caffeine (29) and nitrate (NO3-) (19) supplementation in the Stroop Test. However, no other studies were found that investigated capsaicin supplementation and cognitive performance in sport, which limits the discussion of the results and indicates the need for new studies on this topic. The present study presents a limitation when evaluating cognitive function, since reaction time alone may be insufficient to define cognition in the modality.

In relation to biopsychological parameters, when analyzing the PRS proposed by Laurent *et al.* (20), it was identified that the volunteers were recovered before the experimental sessions, indicating that possible accumulated fatigue did not affect performance in both experimental conditions. Regarding RPEsession and RPEtest, no significant differences were found between capsaicin supplementation and placebo. This result was similar to those found by several other studies (7, 8, 21, 36, 37, 45). However, some studies reported a positive effect on reducing RPE with capsaicin supplementation (3, 5, 38). The justification presented by these studies is related to the desensitization of afferent nerve terminals, reducing the sensation of discomfort and perception of effort. In the specific protocol of the present study, this possible effect was not enough to influence RPEsession and RPEtest in the demand imposed on Taekwondo athletes and para athletes, also indicating a possible specificity in relation to the demand and to the individual.

The results of the lactate blood concentration demonstrated that the responses were similar in both experimental conditions. The same result was reported by Freitas *et al.* (3), Freitas *et al.* (5), Freitas e*t al.* (7) and Ah Morano *et al.* (37), who investigated the effect of acute capsaicin supplementation on different exercise protocols, as capsaicin can increase the oxidation of substrates, sparing muscle glycogen (43). However, the results of this and other studies indicate that capsaicin may not be effective in significantly increasing anaerobic lactic mobilization. Therefore, measuring blood lactate may be unnecessary in future studies. The results of the present study indicate that blood glucose levels increased significantly only in the PLA condition, but not sufficiently to be significantly different from the CAP condition. Some authors (42, 43, 46) suggest that capsaicin can reduce the mobilization of circulating glucose. However, this potential effect was not sufficient to alter the contribution of the lactic energy system, as evidenced by the behavior of lactate concentration. Finally, this response did not affect physical and cognitive performance.

In addition to the limitations presented throughout the text

so far, it is important to highlight that the present study has other limitations. The sample size may be limited, despite being representative in relation to the selection and inclusion criteria. Also, other cognitive aspects were not measured through other tests, mainly specific to the modality. Furthermore, the results should be considered with caution by nutritionists, athletes and coaches in Taekwondo training, as this is possibly the first study on capsaicin supplementation in Taekwondo. Given this, the present work has advanced in science, but new studies are important to improve protocols for capsaicin supplementation in Taekwondo, in different dosages, administrations of the substance, characteristics of athletes and in combat itself, with the aim to robustly evaluate the effectiveness of this nutritional strategy.

CONCLUSIONS

Acute capsaicin supplementation may not be effective in improving the physical and cognitive performance of Taekwondo athletes and para athletes. Furthermore, supplementation may not reduce the Rate of Perceived Exertion (RPE) of Taekwondo athletes and para athletes during general and specific physical tasks. Additionally, capsaicin supplementation does not alter responses to blood lactate and glucose concentration.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

RS, RN, MD: data curation, formal analysis, writing – original draft. MD, RN, MM, GA, AS, MM, RS: writing – review & editing.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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