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Research Article

The effects of the acute consumption of sodium bicarbonate and caffeine on anaerobic power and the level of biochemical indices of fatigue in elite male cross-fitters

Mahdi Rezagholizadeh [*1], Reza Behdari [2] *, Arash Tork Sameni[3], Neghin Joz-e-piri[4], Leila Borjkhani[5]

1. Department of Physical Education and Sport Sciences, Zanjan Branch, Islamic Azad University, Zanjan,Iran
2. Department of Physical Education and Sport Sciences, W T.C., Islamic Azad University, Tehran, Iran.
3. Department of Physical Education and Sport Sciences, Zanjan Branch, Islamic Azad University, Zanjan,Iran
4. Department of Physical Education and Sport Sciences, Zanjan Branch, Islamic Azad University, Zanjan,Iran
5. Department of Physical Education and Sport Sciences, Zanjan Branch, Islamic Azad University, Zanjan,Iran

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Abstract

Background: This study is designed to investigate the effects of acute sodium bicarbonate and caffeine administration on anaerobic power levels and biochemical markers of fatigue present in elite male CrossFit athletes' blood before a training session.

Materials and Methods: The research included 20 male athletes skilled in CrossFit who volunteered to participate. They were randomly categorized into four groups: the sodium bicarbonate group (5 participants), the caffeine group (5 participants), the sodium bicarbonate and caffeine combination group (5 participants), and the placebo group (5 participants). The first group ingested 3mg of sodium bicarbonate per kg/BW, whereas the second group ingested 6mg of caffeine per kg/BW. The third group followed the same protocol, ingesting sodium bicarbonate and caffeine, which were provided in gelatin capsules one hour before their rigorous CrossFit workout. The placebo group consumed pills containing cellulose. The Burpee and Thruster movements were among the most arduous workouts. Following the conclusion of these exercise sessions, all participants undertook the RAST assessment. Blood samples were collected from fasting patients before and after these events to document and assess glucose, ammonia, and lactic acid variations. The hypotheses of this study were evaluated using the MANCOVA test with a significance threshold of P≥0.05.

Results: The group that received caffeine and sodium bicarbonate demonstrated significantly higher maximal and average anaerobic power than the placebo group. Nonetheless, the observed difference was minimal when evaluated against the outcomes of the caffeine or sodium bicarbonate groups administered individually. Conversely, the tiredness index variable in the same combination group was significantly lower than that of the caffeine or sodium bicarbonate groups. Nevertheless, this disparity was negligible in comparison to the placebo group. Compared to the placebo group, the simultaneous consumption of caffeine and sodium bicarbonate resulted in a significant decrease in lactic acid and ammonia levels in blood samples collected post-training. No statistically significant changes in glucose levels were seen across the groups (P<0.05)

Conclusion: The findings indicate that the combined ergogenic effects of caffeine and sodium bicarbonate can enhance anaerobic performance while mitigating fatigue and its associated biochemical markers through simultaneous consumption.

Keywords:
sodium bicarbonate, caffeine, CrossFit, fatigue, anaerobic power

***Corresponding author:** Mahdi Rezagholizadeh, Reza Behdari
Address: Department of Physical Education and Sport Sciences, Zanjan Branch, Islamic Azad University, Zanjan,Iran.
Email: Mahdi_rezagholizadeh@yahoo.com **Tell**:
M R: 0000-0001-7271-4473

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1. Introduction

Performing intense physical exercises could disrupt cellular hemostasis and lead to the production of metabolites. In other words, high-intensity bouts of physical exercise could increase the levels of lactic acid and hydrogen ion and decrease the pH of the blood, subsequently resulting in fatigue (1,2). CrossFit is a high-intensity exercise fitness regimen which has gained significant attention amongst athletes. It is an interval-based training routine and is based on the idea that the shorter and more intense an exercise, the more effective it can be. Repeatedly performing maximum-intensity moves without resting properly in-between can cause fatigue more quickly due to the lack of appropriate recovery time (2). Fatigue can negatively affect the performance of CrossFit athletes and is usually caused by weak muscles, unprepared aerobic and anaerobic systems, energy discharge, and the aggregation of lactic acid and cell metabolites. It could also affect the energy production levels of the athletes and their ability to maintain the required strength. Thus, both researchers and athletes aim to find new and effective solutions to reduce these effects (3,4).

There are several methods of battling these negative effects, which include consuming supplements such as keratin, glutamine, vitamins, carbohydrate drinks etc. Numerous studies have analyzed the effects of each of these items, some of which have confirmed the effectiveness of these supplements on muscle performance and reducing the subsequent fatigue (5). Supplements containing multivitamins and minerals, taurine and energy drinks, caffeine and sodium bicarbonate supplements have also said to be effective in reducing the effects of fatigue and improving physical performance (6, 7).

Recently, caffeine and sodium bicarbonate supplements are being used to improve physical performance and prevent fatigue. The ergogenic effects of caffeine and sodium bicarbonate during high-intensity bouts of exercise have been observed and it has been proven that the two supplements could improve performance and reduce fatigue after training (8).

Caffeine has been on high demand due to its effects on the central nervous system – and the subsequent improvement of consciousness and focus – muscle force generation and lipid metabolism and its ease of use (3, 9). Accordingly, Sassone (2016) believes that considering the increase in caffeine consumption amongst athletes prior to training sessions, it could have significant effects on improving strength and endurance, while also improving performance in strength exercises (10). It seems that the ergogenic effects of caffeine on exercise performance, increasing the release of norepinephrine and dopamine, and enhancing alertness, as well as reducing pressure, fatigue, and perceived pain during exercise (11). Caffeine could also reduce glycogen depletion speed during long bouts of exercise and consume stored fat as the energy source (12). Numerous studies have also confirmed its ergogenic effects (1, 3, 4). Sodium bicarbonate is also on high demand amongst athletes aiming to improve performance and reduce fatigue. A meta-analysis found that caffeine and sodium bicarbonate similarly improve performance in athletes (13). While both are ergogenic individually for various exercises, studies on their combined effects are limited, particularly on acute strength outcomes (14, 15).

Studies suggest that consuming this supplement could increase blood pH and alkaline properties. Consuming sodium bicarbonate can perhaps prove effective in recovering anaerobic energy system, lowering muscle acidity level and increasing the buffer capacity of the body through reducing lactic acid production and muscle acidity. It could also improve muscle performance (15). Zabala et al (2008) confirmed that consuming sodium bicarbonate prior to performing athletic exercises could affect anaerobic power and improve performance, while reducing acidity through affecting acidic interstices and increasing the number of hydrogen ions in muscles, and improving the sodium and potassium pumps in cell membranes(16). Based on the evidence on strengthening and fatigue reducing effects of caffeine and sodium bicarbonate and according to several findings that demonstrate the effectiveness of the combined consumption of the two supplements on fatigue levels in 45-second to 8-minute sports (6, 8), and also considering the high-intensity nature of CrossFit which results in different forms of fatigue, this paper aims to study the individual and combined acute effects of the two supplements on anaerobic performance and the biochemical indices of fatigue in blood samples. Thus, it aims to study the effects of the acute consumption of sodium bicarbonate and caffeine individually and in combination prior to a single CrossFit training session on anaerobic performance and the level of biochemical indices of fatigue in blood samples of elite male CrossFit athletes.

2. Materials and Methods

Research plan: The research plan was carried out on a pretest-posttest design with a dependent-posttest variable, while conducting a single-blind supplementation on three experimental groups and a single control group. On the day of the experiment, subjects arrived at the predetermined location after 12 hours of fasting and 8 hours of sleep. Blood samples were taken from the subjects prior to having a similar breakfast and two hours before the start of a high-intensity exhausting training session. In order to remove the effects of having different amounts of calorie during breakfast, subjects were given a standard set of breakfast at 8 a.m. During the supplementation process an hour later, the first, second and third groups consumed caffeine, sodium bicarbonate, and a combination of the two respectively, while the fourth group was given placebo (cellulose). The second set of blood samples were taken after the consumption of supplements and prior to beginning the CrossFit training session. After collecting the samples, subjects began their high-intensity CrossFit sessions based on a competitive program and took part in an anaerobic RAST test immediately after. Subsequently, the third set of blood samples were taken immediately after the RAST test. These samples were used to determine and analyze glucose, ammonia and lactic acid levels.

Subjects: 20 elite male CrossFit athletes from Zanjan, with a minimum experience of regular triweekly CrossFit sessions and regional and national honors in the same sport, volunteered to take part in the study. A letter of consent and a questionnaire were filled out by the subjects after being informed of the whole process, the aims, advantages and possible damages of the process and the demands of the researcher. Subjects were asked to refrain from consuming caffeinated consumables. Based on the results of a single Burpee race and through the pairing method, subjects were divided into four groups: The caffeine group, the sodium bicarbonate group, the combination group and the placebo group (table 1).

Table 1. Initial stats of the subjects (average±standard deviation)

Variable	Sodium bicarbonate	Caffeine	Sodium bicarbonate+caffeine	Placebo
Age (year)	23±6.1	23.6±4.5	23.8±3.9	26.4±4.3
Height (cm)	179.2±6.1	179.6±4.7	171.2±6.2	176.5±3.8
Weight (kg)	73.7±10.1	79.2±7.1	75.1±9.2	76.2±8.9
Fat percentage	12.6±4.8	14.1±3.6	11.6±4.8	15.7±7.5

Height and weight measurement: IRASALL – manufactured by Sahand Co. in Iran –with an accuracy of 1mm was used to measure height. A digital scale – manufactured by Sahand Baskool, Iran – with an accuracy of 100g was used to weigh the subjects. Furthermore, a skinfold caliper – Lafayette model 01128, made in USA – with an accuracy of 0.1mm and the Jackson-Pollock body formula (1985) were used on the triceps, the hip and thighs to measure the body fat percentage.

Blood sampling and analysis: The sampling process was carried out rounds: fasting period and before and after the end of the training session. After placing the samples in the appropriate environment and after the formation of blood clots, the blood serum was separated and sent to the laboratory for the required indices to be analyzed. In order to obtain blood serum, a serum-separating tube was used and the samples were allowed to clot for 33 minutes prior to the start of the centrifugation process, after which the samples were centrifuged with a speed of 3500rpm for 7-15 minutes. The serums were immediately transferred to the laboratory in a -20°C container. The PAP-GOD method with MIDRAY BS800 and the Pars Azmoon kit to measure the glucose levels of the subjects. Their blood ammonia levels were measured using the ROCHE kit in combination with the ENZYMATIC device and the COBAS C311 method.

Also, the COBAS C311 method and the ROCHE kit were used in combination with the COLORIMETRIC device to measure lactic acid levels.

Anaerobic power test: The RAST test was used to measure the anaerobic power of the subjects. Ultimately, the levels of maximum power, minimum power, average power and the fatigue index were calculated using their respective formulas.

CrossFit exercise: The current study included a high-intensity CrossFit competition, which consisted of the thruster and burpee moves. These moves were performed without rest and with full power in three consecutive sets of 21, 15 and 9. The competition was accurately based on the standards and the regulations of the national CrossFit association and was overseen by official referees. For the Thruster move, a 20kg barbell was held near to the chest and a combination of front squat and overhead press moves was performed. The burpee move consisted of a combination of air squats, Swedish pushups and jumping.

Supplementation: The supplements were given to subjects an hour before training and after having a standard breakfast. The placebo group received cellulose powder – microcrystalline cellulose, China – in gelatin capsules, which were similar in shape, color and smell to the other supplement capsules. The caffeine group – Karen Co., Iran – received 6mg of caffeine in gelatin capsules for every kilogram of their bodyweight (1).

The sodium bicarbonate group – Moein Co., Iran – received 6mg of sodium bicarbonate in gelatin capsules for every kilogram of their bodyweight. The combination group also received 6mg of each substance in gelatin capsules per 1 kilogram of their bodyweight. All subjects consumed their capsules with 100cc of drinking water.

Statistical method

Descriptive statistics was utilized to summarize, categorize and introduce the data distribution method, while the Shapiro-Wilk test was used for testing the normality of the data. MANCOVA test was also used with a p≥0.05 level of significance to test the hypotheses of the current study.

3. Results

The results suggest a significant difference between the four groups in the levels of maximum power and average anaerobic power and the fatigue index (figure 1). The maximum power and average anaerobic power variables were significantly higher in the caffeine+sodium bicarbonate combination group compared to the placebo group, while there was no significant difference when compared to the sodium bicarbonate and caffeine groups. However, the caffeine+sodium bicarbonate group had a significantly lower fatigue index when compared to the caffeine or sodium bicarbonate groups, while no significant differences were observed when compared to the placebo group. No significant differences were observed in the levels of the three variables amongst the other three groups. There were no significant differences in the maximum power, average anaerobic power or the fatigue index of the caffeine group and the other two groups (p=0.05). Regarding the biochemical indices of fatigue, the results show a significant increase in the levels of lactic acid and ammonia after a training session compared to their initial levels prior to training (p≤0.05).

In comparison with the placebo group (figure and table 2), an individual analysis of lactic acid confirmed a significant difference in the two groups of caffeine (p=0.039) and sodium bicarbonate+caffeine (p=0.031). An individual analysis of ammonia levels in blood samples confirmed that all three experimental groups of caffeine (p=0.044), sodium bicarbonate (p=0.046) and sodium bicarbonate+caffeine (p=0.038) had significantly different ammonia levels compared to the placebo group (table 2). There were no significant differences in ammonia, lactic acid or glucose levels between the three experimental groups (p≥0.05).

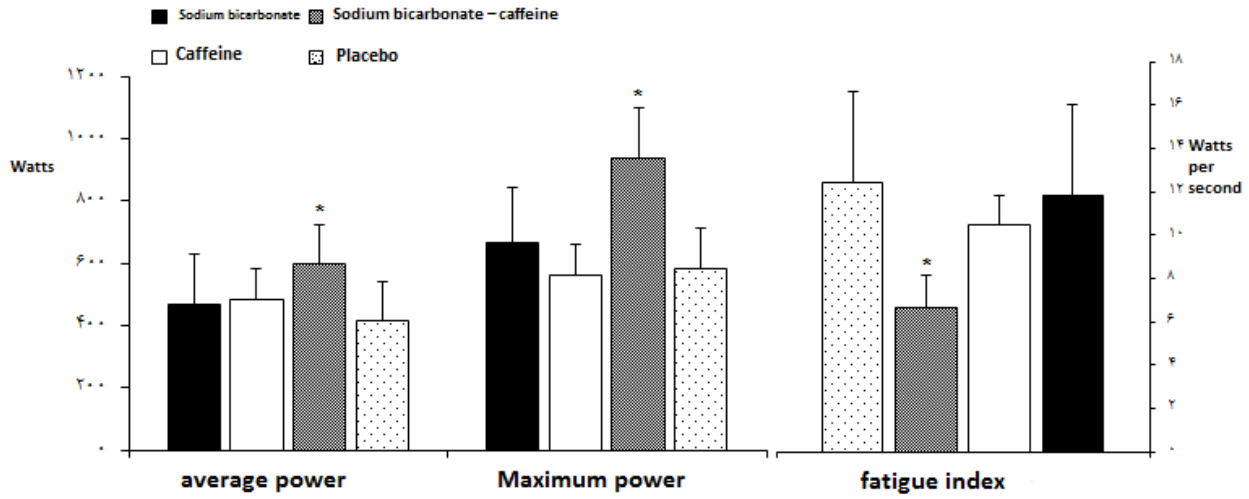

*Figure 1. A comparison between power levels and fatigue indices (average±standard deviation) *significant difference in comparison with the placebo group (p≤0.05)*

Table 2 Observed changes in the biochemical indices of fatigue (average+standard deviation)

Variable		Group			
		Sodium bicarbonate	**Caffeine**	**Sodium bicarbonate + caffeine**	**Placebo**
Lactic acid	Fasting	11.6±3.2	16.6±2.9	11.4±3.5	13.5±4.7
	Pre-exercise	15.6±5.2	17.5±2.1	16.32±3.6	15.6±3.8
	Post-exercise	*95.5±33.6	†*103.4±20.1	†*105.4±32.2	*49.8±18.1
Ammonia	Fasting	71.2±2.4	83.5±33.3	58.8±15.1	55.2±17.6
	Pre-exercise	71±14.1	70.4±22.5	58.1±10.5	73.2±20.5
	Post-exercise	†*280.5±93.7	†*281.1±111	†*268.6±112.1	*100.1±35.8
Glucose	Fasting	97.8±6.1	98.1±12.2	91.1±11.7	84.4±22.3
	Pre-exercise	101.6±11.8	111.2±17.9	103.4±12.8	105.4±8.1
	Post-exercise	109.4±18.8	116.8±22.4	120.6±29.9	107.6±9.1

*= significant difference compared to the pre-exercise period (p≤0.05)

†= significant difference compared to the placebo group (p≤0.05)

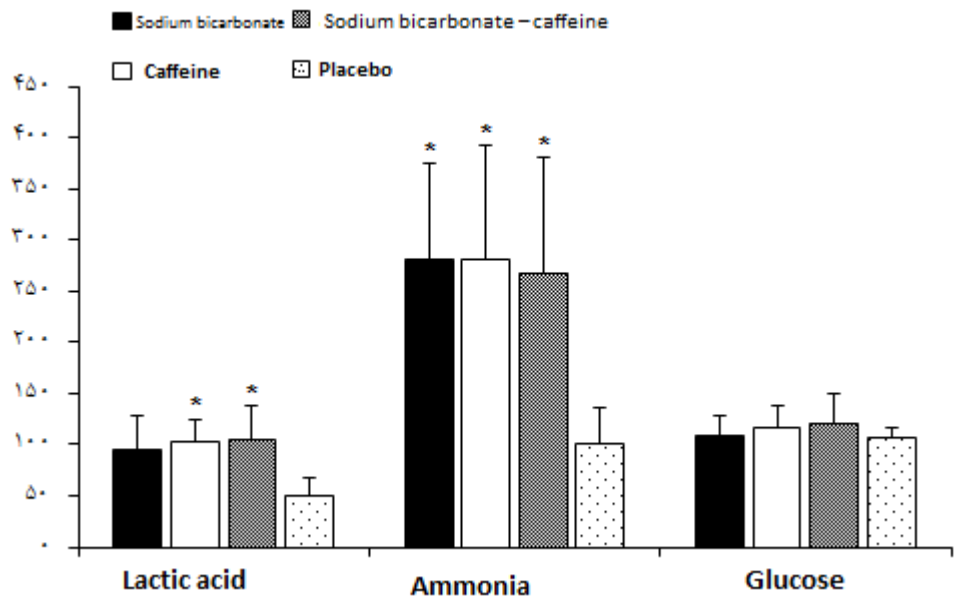

Figure 2 A comparison of the biochemical indices of fatigue between the groups in the post-exercise period (average±standard deviation)

*= significant difference compared to the placebo group (p≤0.05)

4. Discussion

The results of the current study suggest that the acute consumption of sodium bicarbonate combined with caffeine could increase the maximum and average anaerobic power and reduce fatigue in elite male cross-fitters. Having conducted a similar study with caffeine and sodium bicarbonate, Rezaei et al (2019) and Marriott et al (2015) confirm the same results (5,6). Rezaei et al (2019) conducted an experiment to examine the effects of sodium bicarbonate and caffeine supplements and their combination on the fatigue index and observed that consuming these supplements, combined or individually, can improve the fatigue index. However, Grgic et al (1393) have reported the ineffectiveness of these supplements on the fatigue index, which could be due to differences in dosage, time of consumption and the level of fitness the subjects were in (12). Considering the effects of the sodium bicarbonate and caffeine combination on power levels and the fatigue index, it could be claimed that this combination could also reduce lactic acid and pH levels, which could lead to the regulation of effects causing a decrease in anaerobic power and an increase in fatigue levels in athletes, which would ultimately prevent any disruption in the energy generation process of the muscles (15). Following the reduction of muscle acidity and the increase of blood pH level and buffer capacity of the body, sodium bicarbonate supplements could in fact prevent muscle strength deterioration by reducing the lactic acid production rate. As a buffer substance, sodium bicarbonate is able to provide extra resistance against fatigue (16). By increasing the bicarbonate buffer capacity of the blood, improving lactic acid and hydrogen ion transport and by preserving the pH level, this supplement is also able to delay fatigue and increase body's capacity for anaerobic moves and exercises which take between 60-240 seconds to complete (16, 17).

The caffeine supplement is known for stimulating the central nervous system (18) and is able to delay fatigue and reduce glycogen consumption by using fat as the source of energy instead. By increasing the value of free fatty acids and reducing glycolysis and lactic acid in blood, caffeine can delay reaching the fatigue threshold in athletes and increase their capacity for high-intensity physical activity (19,20). Therefore, combining the two supplements could prove to be effective in preventing premature fatigue and increasing anaerobic capacity. Perhaps consuming these supplements lowers muscular acidosis – which is caused by high-intensity and exhausting activities and lowers the efficiency of muscle contraction – and improves intercellular space for a better action potential and contractility. In a review article on the consumption of caffeine and sodium bicarbonate supplements or their combination on physical performance and fatigue, Grgic (2020) observed that consuming the two supplements can have positive physiological and ergogenic effects on performance without any significant side effects (21). However, the effects of this combination need to be studied further in other sports.

The results of the current study also showed that the acute consumption of sodium bicarbonate and caffeine combined or individually prior to physical activity, significantly lowered ammonia and lactic acid levels in blood samples compared to the placebo group after a high-intensity and exhausting workout. However, these supplementations had no significant effects on the glucose levels. Most of the relevant studies have examined the effects of these supplements individually Hamidi 1397;Sharifi et al 1392; 24.Grgic et al. 2021) and most have reported that consuming sodium bicarbonate could affect lactic acid and ammonia levels, reduce fatigue and increase power in athletes (٢٢,٢٣,٢٤).

On the other hand, several researchers – including Grgic et al (٢٠١٧), Danković et al (2022) – have reported that consuming this supplement has no effects on ammonia levels and lactic acid in blood (12,25). Ammonia is produced through protein decomposition and is connected to the process of fatigue (26,27). High-intensity workouts lead to the concentration of ammonia in the cerebrospinal fluid, which could potentially cause central and peripheral fatigue . Ammonia accumulation during workout sessions generally depends on muscle ammonia density and its elimination from active muscles ,Lactic acid is the final product of anaerobic digestion and is accumulated in muscles and the blood following athletic activities . Regulating lactic acid could prevent performance decline. In other words, limiting the production of these metabolites can help athletes improve their performance and continue further on maximum power with optimal capacity. In fact, consuming sodium bicarbonate supplements could be an important factor in increasing the buffer capacity and the transport of hydrogen ion and lactic acid, while also leading to the disposal of lactic acid and subsequently preventing the production of ammonia (11,24).

Consuming caffeine can increase blood flow by increasing vascular expansion and the activity of the sympathetic system. As a result, increased blood flow from muscles to the respiratory system could play an important role in supplying oxygen and consequently lowering lactic acid and ammonia levels. Considering the fact that there are no differences between individual and combined supplements, it could be claimed that extra consumption of the two supplements in combination was not successful in having more physiological effects on the regulation of lactic acid and ammonia (ibid).

Based on the fact that no changes were observed in glucose levels, it could be claimed that blood glucose levels are affected neither by the two individual supplements nor by their combination. Of course little information is available on this variable and it needs to be studied further.

5. Conclusion

Based on the results of the current study, consuming a combination of sodium bicarbonate and caffeine supplements prior to an high-intensity and exhausting workout session could have more effects on improving anaerobic performance and the fatigue indices in the blood compared to consuming a placebo or any of the two supplements individually. Thus, a combination of sodium bicarbonate and caffeine can be consumed to improve anaerobic performance in high-intensity workout sessions and sports such as CrossFit.

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Compliance with ethical standards

Conflict of interest None declared.

Ethical approval the research was conducted with regard to the ethical principles.

Informed consent Informed consent was obtained from all participants.

Author contributions

Conceptualization: M.R, R.B, A.T.S, N.J,E.P, L.B.; Methodology: M.R, R.B, A.T.S, N.J,E.P, L.B.; Software: M.R, R.B, A.T.S, N.J,E.P, L.B.; Validation: M.R, R.B, A.T.S, N.J,E.P, L.B.; Formal analysis: M.R, R.B, A.T.S, N.J,E.P, L.B.; Investigation: M.R, R.B, A.T.S, N.J,E.P, L.B.; Resources: M.R, R.B, A.T.S, N.J,E.P, L.B.; Data curation: M.R, R.B, A.T.S, N.J,E.P, L.B; Writing - original draft: M.R, R.B, A.T.S, N.J,E.P, L.B.; Writing - review & editing: M.R, R.B, A.T.S, N.J,E.P, L.B.; Visualization: M.R, R.B, A.T.S, N.J,E.P, L.B.; Supervision: M.R, R.B, A.T.S, N.J,E.P, L.B.; Project administration: M.R, R.B, A.T.S, N.J,E.P, L.B.; Funding acquisition: M.R, R.B, A.T.S, N.J,E.P, L.B.

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