Acute capsaicin supplementation and heart rate variability in a weight training session

Suplementação aguda de capsaicina e variabilidade da frequência cardíaca em uma sessão de treino de musculação

Marcos Dante Santos Caldas
Sports Nutrition and Training Laboratory (LAN) - Federal University of Minas Gerais (UFMG)

Amadeus Victor de Andrade Araujo
Sports Nutrition and Training Laboratory (LAN) - Federal University of Minas Gerais (UFMG)

Matheus Dias Mendes
Sports Nutrition and Training Laboratory (LAN) - Federal University of Minas Gerais (UFMG)

Marcos Daniel Motta Drummond
Sports Nutrition and Training Laboratory (LAN) - Federal University of Minas Gerais (UFMG)

Keywords: Weight training, Supplementation, Heart rate.

1 INTRODUCTION

Several varieties of chili peppers are produced and consumed in practically all of Brazil (DE CARVALHO et al., 2006), being in third place among the vegetables most used as seasoning (LIMA, 2012). Among them, there are those of the genus Capsicum, being the chili peppers malagueta, de-cheiro, dedo de moça, pimentão and jalapeño, some of the representatives of the group (Aquino, 2016).

Capsaicin (8-methyl-Nvanillyl-trans-6-nonenamide) is a phenol present in chili peppers (GRGIC et al., 2022; MONSEREENUSORN et al., 1982), considered the main active compound that guarantees their spicy flavor, responsible for up to 70% of the burning (LUDY; MOORE; MATTES, 2012).

Capsaicin (CAP) is an agonist at the transient receptor potential vanilloid subtype 1 (TRPV1) (LUO et al., 2012). These receptors were initially detected in several primary afferent sensory neurons of the dorsal root ganglia, trigeminal and vagal ganglia (BEVAN; QUALLO; ANDERSSON, 2014; JORGENSEN; DOMENE, 2018). In addition, TRPV1 is expressed in non-neuronal cells such as adipose tissue, hepatocytes, skeletal muscle, smooth muscle, cardiac and endothelial cells (AGHAZADEH et al., 2016; BEVAN; QUALLO; ANDERSSON, 2014; COSTA et al., 2020).

The TRPV1 receptor is a calcium channel that opens when it comes into contact with capsaicin, which, from the influx of these ions, releases neurotransmitters capable of expressing heat, at low concentrations of CAP, up to pain, at high concentrations (CATERINA et al., 2000). When capsaicin comes into contact with the oral cavity, it is diffused through the tongue and selectively binds to these receptors, bringing the classic burning sensation when consuming chili peppers (LUDY; MOORE; MATTES, 2012). Following the gastrointestinal tract, this phenol is passively absorbed in the stomach and upper portion of the small intestine, binding with high affinity to the TRPV1 receptor (IWAI; YAZAWA; WATANABE, 2003; KAWADA et al., 1984).

The consumption of CAP, through foods containing pepper or through supplementation itself, is widely studied by several researchers, since its intake can lead to different physiological consequences in the body (FOSHATI et al., 2021; JIANG et al., 2022; ZHANG et al., 2023). Snitker et al. (2009), was able to associate oral capsaicin supplementation with increased lipid oxidation and, consequently, with abdominal fat loss (SNITKER et al., 2009). Other research has also identified a modulatory effect on blood lactate increase during exercise, in addition to the ability to increase liver glycogen, with CAP supplementation, effects that lead to a reduction in muscle fatigue (HSU et al., 2016). One more example is a potential analgesic effect due to the possible inactivation of nerve endings affected by calcium overload that happens when activation of TRPV1 receptors occurs (CATERINA et al., 2000; LEBOVITZ et al., 2012), which could increase the pain threshold and minimize the discomfort induced by strenuous exercise (DE FREITAS et al,. 2022).

Due to these physiological effects, capsaicin began to be used as a study tool in order to evaluate its potential ergogenic effect, defined as substances, synthetic or natural, used to alter sports performance (MOMAYA; FAWAL; ESTES, 2015).

De Freitas et al. (2022) found that acute supplementation of 12 mg of CAP (12 mg 45 minutes before and another 12 mg immediately before the training session), was able to improve the volume/load ratio in resistance exercise and to promote a decrease in the average heart rate and PSE during a session of intermittent high-intensity exercise compared to a placebo group (DE FREITAS et al., 2022). In a study by Picone et al., (2021) a decrease in PSE was also noticed in the group that consumed capsaicin, but this time, it was during a Crossfit session, which would allow a decrease in the discomfort generated during training and competitions of this modality (PICONI et al., 2021). These effects may have occurred due to both the potential analgesic effect of CAP and the modulation of TRPV1 channels, stimulating a greater influx of calcium and a better interaction between actin and myosin filaments, promoting greater tension in the muscle (DE FREITAS et al., 2018a and DE FREITAS et al., 2022). The same author also observed that, from these same physiological effects mentioned, supplementation by physically active men led to a decrease in PSE and increased performance in a 1500m race (DE FREITAS et al., 2018b).

In the scientific literature, the ability of PAC to cause changes in the autonomic nervous system (ANS) has been explored, acting mainly by increasing the activity of the sympathetic nervous system (SNS) (ZALESK et al., 2023). To assess the existence of these effects, a non-invasive and reliable method is used, called heart rate variability (HRV). This is defined by the variation in the sequence of time intervals between heartbeats and is strongly influenced by the body's ANS (BERNTSON et al., 1997; VANDERLEI et al., 2009).

The heart is mainly controlled by the upper brain center and the brainstem, through the activity of the ANS (DONG, 2016). The sympathetic and parasympathetic nerves that send signals regulated by the spinal cord are part of the ANS (TRIPOSKIADIS et al., 2009). When the body receives stimuli, whether physical or emotional, is incited a cardiovascular response to such event (MAKIVIĆ; NIKIĆ; WILLIS, 2013). When this stimulus occurs by the sympathetic pathway there is an increase in heart rate (HR), contractility and impulse conduction velocity through the mediation of alpha and beta adrenoreceptors, while parasympathetic stimulation has the opposite effects through the muscarinic receptor (MAKIVIĆ; NIKIĆ; WILLIS, 2013).

As HRV is the beat-to-beat assessment of the heart, it becomes an indirect way of analyzing the stimulation, or not, of the sympathetic nervous system and consequently the ANS (DONG, 2016), as by stimuli of physical exertion, food and supplementation.

This variation in heart rate is also considered an indicator of the adaptive capacity of the cardiovascular system and is affected by several factors, such as the level of physical activity, age, diet and sleep quality (DA SILVA et al., 2015). In addition, it is also an important indicator in the assessment of cardiac health, training load and sports performance (BUCHHEIT, 2014; GROSSMAN; PORTH, 2016; PLEWS et al., 2013).

The use of HRV in sports has been widely studied in the scientific literature. Several studies indicate that HRV can be a valuable indicator in the assessment of physical performance, and can be used, among other parameters, to adjust training load, injury prevention, *overtraining* assessment and aerobic capacity (BOSQUET et al., 2008; DA SILVA et al., 2015; MOUROT et al., 2004). For example, a study conducted with casual runners showed that those who had high HRV had a greater reduction in running time throughout the tests (BUCHHEEIT et al., 2010). Thus, studies relating capsaicin supplementation to HRV are important, because with the alteration of this marker due to supplementation, it may no longer be a reliable parameter for assessing training load control and sports performance.

Studies addressing the effect of capsaicin supplementation on HRV are still very scarce and the existing ones present divergent results. Some studies evaluated this influence in healthy and obese men, respectively, and concluded that CAP supplementation did not result in significant changes in the action of the sympathetic nervous system, measured through HRV (SHIN AND MORITANI, 2007 and 2008). On the other hand, Kono et al., (2018) demonstrated that capsaicin intake by healthy men increased SNS activity, including leading to an increase in metabolism (KONO et al., 2018).

This divergence of results may be a possible indication of a difference in responsiveness to CAP among individuals. Simões et al., (2021) evaluated trained men, of whom, although the group as a whole did not show significant benefits with CAP supplementation, some specific individuals did, bringing this hypothesis of different responsiveness (SIMÕES et al., 2021). This phenomenon also occurs with other substances, such as caffeine, for example, has its absorption and effects varying between each consumer due to several factors such as sex, weight, genetics, among others (GUEST et al., 2019; MINERS; BIRKETT, 1996). Thus, a variation in HRV may indicate whether an individual is responsive to PAC supplementation, with a possible ergogenic effect on sports performance.

So, although the studies provide preliminary evidence of a possible relationship between PAC and HRV, more research is still needed to understand the influence of supplementation on this autonomic nervous system response.

2 OBJECTIVE

To assess whether capsaicin supplementation in trained men will result in a change in heart rate variability.

3 METHODOLOGY

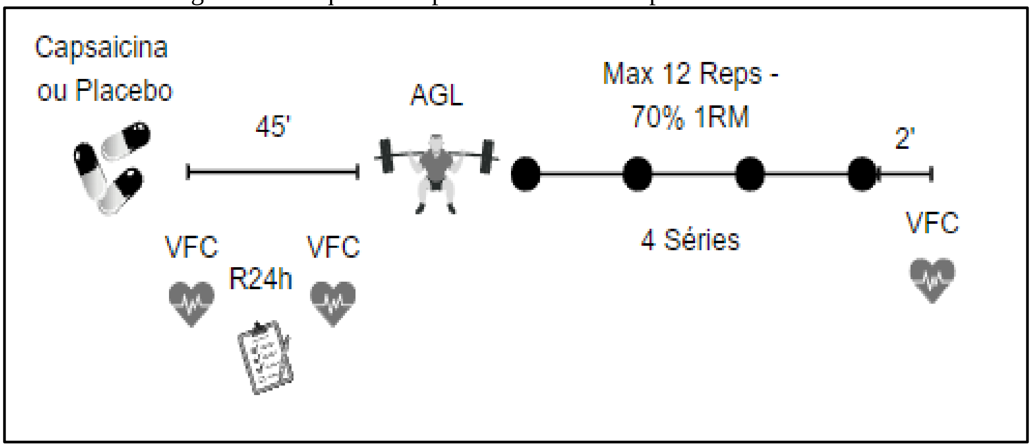
3.1 EXPERIMENTAL DESIGN

This study was a cross-sectional experimental study with a randomized, double-blind, crossover design. Blinding and randomization were performed by an external researcher who was not directly associated with the research data. Each volunteer had 7 visits, with an interval between 72 and 96 hours between sessions, performed at the same time of day.

The first meeting aimed to present the research and characterize the sample, recording the volunteer's social data, time of experience in bodybuilding (in months), weekly training frequency and performing the evaluation of the body composition of the same. Still in the first meeting, the environment, equipment and tests to be performed were presented, for the volunteer to familiarize himself with the research. The 24-hour food recall (R24h) was also performed for the same characterization purpose.

The following meetings were intended for experimental sessions. On the second and third visit, individuals performed the 1 RM test, used to define the weight that would be used in the free squat exercise (FSA). In the following four sessions, the volunteers randomly and blindly consumed capsaicin (CAP) or placebo (PLA) and underwent FFA, in addition to measuring heart rate variability (HRV) and collecting the food recall. Figure 1 exemplifies how the experimental sessions were performed. The sessions were performed twice in each condition, in order to measure the reliability of the results (ATKINSON; NEVILL, 1998; WEIR, 2005).]

Figure 01 - Sequence of procedures of the experimental sessions.



Source: prepared by the authors.

During the meetings, all volunteers were instructed to have their last meal 60 minutes before the start of the session. In addition, they were instructed to maintain their usual food consumption, in addition to replicating the pre-workout meal performed in the first experimental session. This was done in order to guarantee the participants' dietary pattern, avoiding interference in the research.

3.2 SAMPLE

The sample consisted of 7 men (mean age 25.42 ± 5.12 years, height 1.75 ± 0.08 meters, body mass 78.5 ± 9.90 kg, fat-free mass 68.09 ± 5.86 kg and body fat percentage 12.64 ± 7.71%), with an average weight training history of 13.85 ± 5.84 months (frequency of 5.28 ± 0.75 workouts per week).

This sample was obtained by convenience, and the inclusion criteria were: having at least 6 consecutive months of physical training in bodybuilding, with a frequency of at least 3 times a week, and being used to doing the exercise "free squat", in addition to not having used anabolic steroids in the period of 6 months prior to the research. The exclusion criteria were: having some type of lower limb injury or presenting any clinical condition that could interfere with the tests and strength training session.

For the recruitment of volunteers, social networks such as Instagram and WhatsApp were used, as well as dissemination through posters in educational institutions and regional physical and sports training centers.

The individuals were instructed not to start supplementation, either with food or substances, with possible ergogenic capacity during the study, in addition to not consuming spicy foods or stimulating caffeine-based drinks on the day of the collection sessions (DE FREITAS et al., 2018b). In addition, this project respected all the rules established by the National Health Council (Res 466/2012) and was approved by the Research Ethics Committee of the Federal University of Minas Gerais (opinion 6.059.504).

3.3 PROCEDURES

3.3.1 Familiarization

The first visit was made in order to familiarize the volunteers with the tests, questionnaires and procedures that would be performed. Individual data were collected, in which they were asked to answer a questionnaire asking about gender, age, time of weight training, weekly frequency and use of supplements. The R24h was also collected and the meal taken before the session was noted. In addition, a physical assessment was also performed to obtain the volunteers' body composition data. General guidelines were also given on how the study would be, what each participant would need to do and defined the days and times they should attend the site for the tests. Finally, they were taken to the training space to get to know the equipment and the exercises that would need to be performed.

For familiarization with the free squat, all volunteers were instructed to perform the exercise with the weight they were used to, positioning the bar above the posterior deltoids, with the feet shoulder-width apart and pointed slightly outward (BERGSTROM et al., 2018). The knee and hip flexion movement (eccentric phase) needed to be performed until the posterior thigh muscles were parallel to the ground, with an angulation close to 90º (ESFORMES; BAMPOURAS, 2013). A portable precision goniometer was used to verify this angulation. In order to standardize such amplitude, for each volunteer a marking was made with ropes attached to two rods, which were touched when reaching such angulation, and which should be reached to count the repetition of the exercise.

3.3.2 Protocol of the experimental weight training session.

At the first visit, as described, the volunteers were familiarized with the FFA training protocol, in which they performed four sets with up to 12 repetitions, using their usual weight, with an interval of 120s between sets. Participants were instructed to perform the exercise until the established repetition limit or when they reached voluntary exhaustion.

In the experimental sessions, this protocol was repeated after the time of action of the supplementation, being performed at the intensity of 70% of 1RM calculated in the second and third experimental session.

3.3.3 One repetition maximum (1RM) test

For the 1RM test, each volunteer was asked the usual weight displaced in the free squat exercise and the number of repetitions that are usually performed (FONSECA et al., 2020). Then an initial series was performed and, subsequently, a progressive increase of 10% to 15% of the load in each attempt according to the subjective perception of the volunteer and evaluator, respecting a five-minute break between sets (DRAKE; KENNEDY; WALLACE, 2018; FONSECA et al., 2020). When the volunteer could not complete the full range of motion, the weight was considered as 1RM the weight of the previous attempt (FONSECA et al., 2020).

3.3.4 Supplementation protocol

Supplementation was performed 45 minutes before strength tests, as this is the time described in the literature in which the maximum peak absorption of CAP is reached (O'NEILL et al. 2012). Regarding the dosage, it was defined based on the total body mass of the individual, and the dosage was chosen based on the study carried out by De Freitas et al. (2018), which approximates 0.15 mg/kg (DE FREITAS et al., 2018b). In this case, volunteers received capsules containing CAP or placebo (starch), and neither the evaluators nor the study participants knew what would be consumed in that session.

3.3.5 Heart rate variability

Immediately after consuming the supplement, the volunteer put on the heart rate transmitter chest strap (model: H-10; Polar; Brazil), for HR and HRV monitoring.

HRV monitoring was performed at three times: immediately after supplementation, 40 minutes after supplementation and two minutes after the end of the training protocol in the FFA. This monitoring was performed for five minutes, using one minute of signal stabilization. For this, the volunteer needed to be at rest, in a sitting position, in addition to being in constant temperature and humidity conditions (BOURDILLON et al., 2017). The conditions for measuring HR and HRV were repeated on all test days.

To perform this procedure, the smartphone application (Elite HRV, version 5.5.5) was used, a validated and reliable instrument when compared to the electrocardiogram technique, considered the gold standard (MOYA-RAMON et al., 2022).

The square root of the mean of the standard deviations of adjacent R-R intervals (RMSSD), which is a metric in the field of time, was used as a measure for HRV analysis. Noting that HRV measurements do not have a normal distribution, thus, the logarithm of the square root of the mean of the standard deviations of adjacent R-R intervals (lnRMSSD) was also used, to allow a parametric statistical analysis (MICHAEL; GRAHAM; DAVIS, 2017). HRV measurement metrics in the time field were chosen because they present more consistent results (KUSS et al., 2008; MICHAEL; GRAHAM; DAVIS, 2017).

Such measures reflect cardiac parasympathetic modulation, thus being possible to assess potential changes in HR induced by PAC supplementation (DONG, 2016; SHIN et al., 2010).

3.3.6 Food Consumption

Since food could interfere with test performance during the research (DA SILVA et al., 2015), to avoid this situation, the volunteers' intake was monitored through the 24hR. Before each session, right after CAP/PLA supplementation, the food recall was applied and, subsequently, these data were analyzed quantitatively for energy consumption and macronutrients, using the WebDiet® software version 3.0, enabling analysis of the dietary profile (SIMÕES et al., 2021).

3.3.7 Statistical analysis

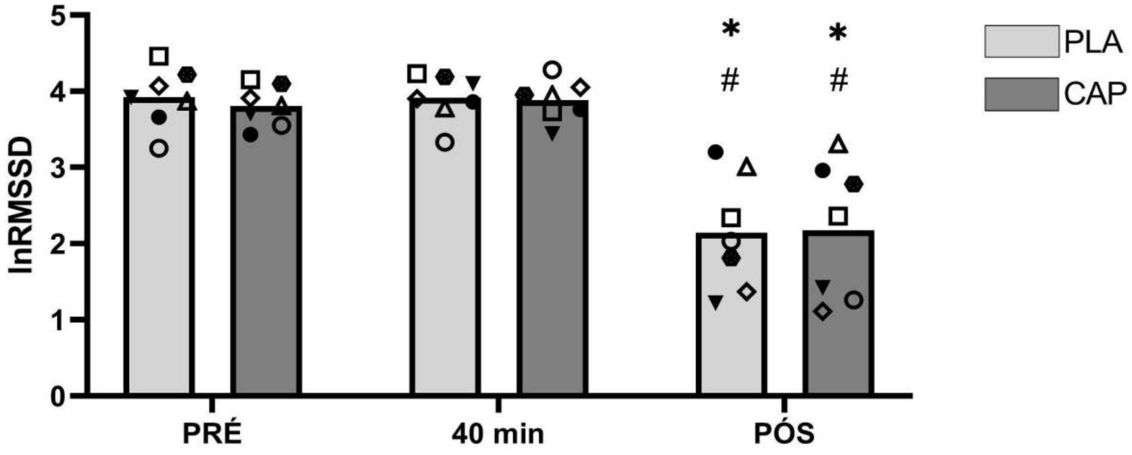
For statistical analysis, a two-way ANOVA of repeated measures was used, considering the moments before, 40 minutes after supplementation and after training, as time factors and CAP or PLA as condition factors. The Mauchly and Greenhouse-Geisser tests were used to verify the sphericity of the data and the correction of the variables that did not present it, respectively. A significance level of $\alpha = 0.05$ was used. SPSS software (version 22.0) was used for data analysis, and GraphPad Prism software (version 9.5.1) and Excel (2019) were used for graphing.

4 RESULTS

From the statistical analysis, it was observed that both in the time factor (pre, 40 min and post) and in the interaction between the time factor and condition (PLA and CAP) the data did not show sphericity for the variable lnRMSSD ($p=0.021$; $p=0.005$). However, for the RMSSD variable, only the interaction of the condition and time factors did not show sphericity ($p=0.010$), considering a significance of $\alpha = 0.05$. Therefore, the Greenhouse-Geisser correction was applied to the variables that did not show sphericity.

When analyzing the lnRMSSD means, it was possible to identify a significant difference between the time factor ($p=0.001$), indicating a change in HRV between the moments before and after exercise. However, no difference was observed between CAP or PLA supplementation ($p=0.628$), showing that capsaicin had no significant effect on the change in lnRMSSD in the group compared to placebo. There was also no significant difference in the interaction between supplementation and the times evaluated ($p=0.727$). These results are illustrated below in Figure 02.

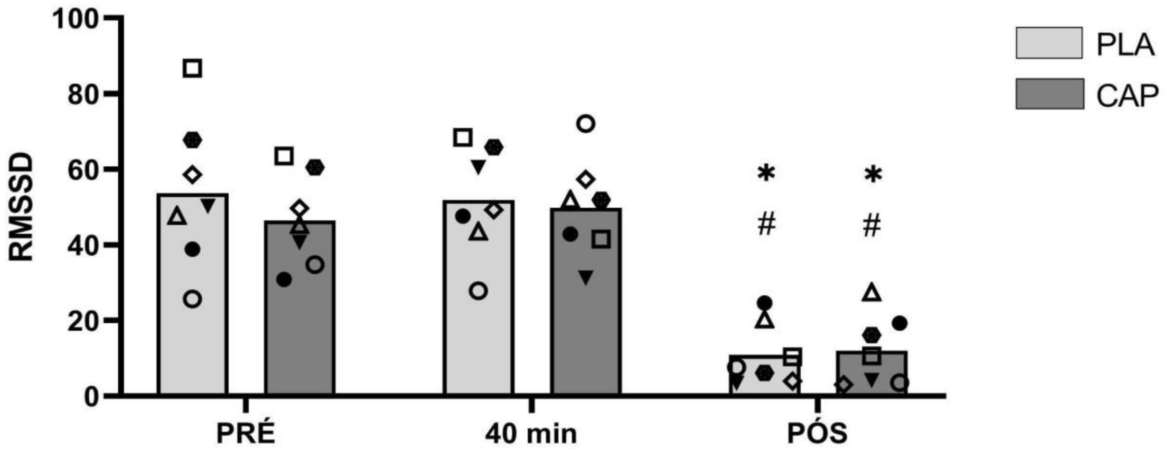
Figure 02 - Means and standard deviations of lnRMSSD of HRV in time and condition factors.



Source: Prepared by the authors.
*Statistically significant difference compared to the PRE moment (p<0.05)
#Statistically significant difference compared to time point 40 min (p<0.05)

Analyzing the RMSSD means, no significant difference was found between PAC or PLA intake (p=0.540). However, a statistical difference was observed when evaluating the isolated time factor (p=0.000), showing that there was a change in HRV between the pre- and 40-minute times with post-exercise. However, like the lnRMSSD, when the interaction between the factors condition and time was evaluated, no significant effect was observed in the analyzes (p=0.474). These results are illustrated in Figure 03.

Figure 03 - Means and standard deviations of RMSSD of HRV of time and condition factors.



Source: Prepared by the authors.
*Statistically significant difference compared to the PRE moment (p<0.05)
#Statistically significant difference compared to time point 40 min (p<0.05)

In figures 02 and 03, comparing the PLA and CAP condition, it is possible to observe different individual HRV responses in relation to supplementation, measured through lnRMSSD and RMSSD, at pre, 40 min and post times.

5 DISCUSSION

The present study verified the acute effect of capsaicin supplementation on HRV, in trained individuals, in a weight training session, performing 4 sets of the free squat exercise. The results showed a reduction in the mean values of the markers InRMSSD and RMSSD after exertion in both conditions, PLA and CAP, with no significant difference between them. No difference was observed in HRV between the pre- and 40 min moments in any of the conditions, also without significant difference between them. In addition, variations in individual HRV marker results were observed between volunteers in HRV.

Corroborating the present study, Shin and Moritani (2007) instructed healthy men to receive supplementation of PAC capsules (150mg) or PLA, and to do 30 minutes of ergonomic cycling. Measuring the HRV of the participants, no significant difference was found between the supplementations in this parameter, both at rest and during activity. Still, CAP had an effect on increasing lipid oxidation during exercise (SHIN & MORITANI, 2007). Using the same supplementation and training protocol, similar results were found by Shin and Moritani (2008). The results showed that supplementation also did not generate a statistically significant effect on ANS activation measured through HRV (SHIN & MORITANI, 2008). In the present study, different doses were used for PAC supplementation and a different training protocol, but despite this, the results found were the same. A difficulty presented in the studies cited was in the method used for the evaluation of HRV (spectral analysis of HRV), since it takes into account HR, which varies greatly during exercise. In addition, the authors also point out the wide individual variation of HRV ranges, making it difficult to analyze this quantity (SHIN E MORITANI, 2007; SHIN E MORITANI, 2008).

Rossi et al. (2022) also found similar results, but with the supplementation of capsiate, a substance also present in chili peppers, with an effect analogous to that of capsaicin on TRPV1 (LUDY; MOORE; MATTES, 2012). In this study, a group of men consumed capsiate or placebo in the condition of moderate intensity aerobic exercise or control (no exercise). In the exercise condition, no significant differences in HRV were found between participants, however, a difference was observed between the CAP control group and the placebo control on HRV (ROSSI et al., 2022).

One justification for these post-exercise results is a possible overlap of the effects of CAP by the influence of physical activity on the CNS. Since, when starting an exercise, as a natural response of the body, there is a rapid change in the balance between the portions of the ANS. These adjustments, mediated by the central nervous system (CNS), send signals that alter the arterial baroreflex, as well as muscle mechanoreceptors, generating, mainly, a reduction in parasympathetic activity (MICHAEL; GRAHAM; DAVIS, 2017; JAMALI; WAQAR; GERSON, 2017). These changes in sympathetic and vagal tone generate responses that alter HRV (MICHAEL; GRAHAM; DAVIS, 2017; ROSSI et al., 2021). Thus, the changes that PAC supposedly could have caused in HRV, through the analysis of the PNS, could be overlapped by the CNS responses to exercise. This could justify the lack of change in supplementation in post-exercise HRV in the studies of both the aforementioned authors (ROSSI et al., 2022; SHIN AND MORITANI, 2007; SHIN AND MORITANI, 2008) and the present study.

On the other hand, Zaleski et al. (2023) found a significant difference in RMSSD using approximately 2mg of capsaicin (ZALESKI et al., 2023). In the study, participants, 25 men and 13 women, were given either CAP supplementation or placebo and remained at rest for 40 minutes. After this period, it was observed that the RMSSD in men who took CAP increased, while in women it decreased, indicating a possible difference in CAP response between the sexes (ZALESKI et al., 2023).

As in the study by Rossi et al. (2021), Zaleski et al. (2023) found differences in HRV between participants supplementing CAP and PLA, in the resting condition (ROSSI et al., 2022; ZALESKI et al, 2023). In the case of the former, a variation in SNS activity measured through the LF and HF parameters (also used to analyze HRV) was found. However, the authors themselves report the possibility of inconsistencies due to the use of parameters not yet fully understood (ROSSI et al., 2022). In the case of Zaleski et al. (2023), variations in SNP activity were found, using RMSDD as a form of analysis, which is a parameter already proven to evaluate SNP activity (MICHAEL; GRAHAM; DAVIS, 2017).

In this sense, it is known that HRV is a method that can suffer interference from several factors during its measurement, among them the age of individuals, gender and diet (DA SILVA et al., 2015). Considering this, one possibility of the divergence of results between the studies may be the difference in age of the individuals. In Zaleski's study, the volunteers had a lower average age than the participants in the other studies, which could influence the HRV results (GEOVANINI et al., 2020; ZALESKI et al., 2023). It is also worth mentioning the difference in the standardization of the last meal before PAC supplementation. Since, in the study by Zaleski et al. (2023), there was no control or standardization of this last meal, while in the others cited, including the present study, there was an attempt to minimize the disturbance that this variation could cause (ROSSI et al., 2022; SHIN AND MORITANI, 2007; SHIN AND MORITANI, 2008; ZALESKI et al, 2023).

Considering such factors, there is still the possibility of an individual responsiveness to CAP, which would need to be considered when discussing the divergence of results between studies on CAP supplementation and HRV. Simões et al. (2021) studied the supplementation of capsaicin and caffeine in a free squat session and found that some isolated individuals, after ingesting CAP, had an improvement in performance when compared to placebo, although the group average did not show a statistically significant improvement (SIMÕES et al., 2021). Costa et al. (2020) also suggested the idea that there are different individual responses to PAC supplementation, since they identified individuals who responded well to capsaicin and others who did not, in their study evaluating performance in 400 or 3000m races (COSTA et al., 2020). In the present study, similar results were found, where there was no significant difference for CAP supplementation in the sample, but, analyzing the results individually, some volunteers showed a difference in HRV at pre and 40 minutes, comparing the two conditions. There are some hypotheses to justify such a difference in responsiveness, among them is the habitual consumption of foods with peppers (LUDY; MATTES, 2011), since it could reduce the number of TRPV1 receptors and consequently reduce the effect of capsaicin (SALVADOR et al., 2012). Both in the present study and in the other studies mentioned above, there was no assessment of the habitual consumption of peppers and derivatives, making it impossible to analyze this aspect in depth. In addition, this different individual response can also be explained by a genetic variation regarding TRPV1 (FISCHER; CIOTU; SZALLASI, 2020). Finally, it is possible to consider that HRV can be a valid parameter to assess individual responsiveness to capsaicin. However, new research is indispensable to analyze individual volunteers in relation to the changes that capsaicin may or may not cause in the subjects' HRV, associated with physical exercise performance.

Unfortunately, to our knowledge, there are no studies that jointly assess PAC supplementation, sport performance and HRV to obtain an individual response difference between participants. Therefore, further research is needed to prove this hypothesis.

Finally, the sample size is a limitation in this study, as well as in several others mentioned above. This leads to the need for studies with a larger number of individuals to validate the existence, or not, of PAC effects on HRV and whether these effects vary depending on the individuality of the user.

6 FINAL CONSIDERATIONS

Acute capsaicin supplementation may not cause changes in HRV response in bodybuilders at rest or after a training session. In addition, some individuals may have a different HRV response when supplemented with CAP. However, HRV may not be a good parameter to assess the effects and individual responsiveness of PAC supplementation on PNS, either at rest or post-exercise.

REFERENCES

AGHAZADEH TABRIZI, M. et al. Medicinal Chemistry, Pharmacology, and Clinical Implications of TRPV1 Receptor Antagonists. Medicinal Research Reviews, v. 37, n. 4, p. 936–983, 1 jul. 2017.

ATKINSON, G.; NEVILL, A.M. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports medicine, v. 26, n. 4, p. 217-238, 1998.

BERGSTROM, H.C. et al. Examination of a multi-ingredient preworkout supplement on total volume of resistance exercise and subsequent strength and power performance. The Journal of Strength & Conditioning Research, v. 32, n. 6, p. 1479-1490, 2018.

BERNTSON, G. G. et al. Heart rate variability: origins, methods, and interpretive caveats. Psychophysiology, v. 34, n. 6, p. 623–648, 1997.

BEVAN, S.; QUALLO, T.; ANDERSSON, D. A. Trpv1. Mammalian Transient Receptor Potential (TRP) Cation Channels: Volume I, p. 207–245, 2014.

BOSQUET, L. et al. Is heart rate a convenient tool to monitor over-reaching? A systematic review of the literature. British journal of sports medicine, v. 42, n. 9, p. 709–714, 2008.

BOURDILLON, N. et al. Minimal Window Duration for Accurate HRV Recording in Athletes. Front Neurosci, vol. 11.456, 2017.

BRASIL. Resolução nº 466, de 12 de dezembro de 2012. Dispõe sobre diretrizes e normas regulamentadoras de pesquisas envolvendo seres humanos. Diário Oficial [da] República Federativa do Brasil, Brasília, DF, 13 jun. 2013. Disponível em: <Disponível em: http://bit.ly/1mTMIS3 > Acesso em: 15 mai. 2023.

BUCHHEIT, M. et al. Monitoring endurance running performance using cardiac parasympathetic function. European journal of applied physiology, v. 108, p. 1153–1167, 2010.

BUCHHEIT, M. Monitoring training status with HR measures: do all roads lead to Rome? Frontiers in physiology, v. 5, p. 73, 2014.

CATERINA, M. et al. Impaired nociception and pain sensation in mice lacking the capsaicin receptor. science.org, v. 288, n. 5464, p. 306–313, 14 abr. 2000.

COSTA, L. A. et al. Acute capsaicin analog supplementation improves 400 m and 3000 m running time-trial performance. International Journal of Exercise Science, v. 13, n. 2, p. 755, 2020.

DA SILVA, V. P. et al. Heart rate variability indexes as a marker of chronic adaptation in athletes: a systematic review. Annals of Noninvasive Electrocardiology, v. 20, n. 2, p. 108–118, 2015.

DE CARVALHO, S. I. C. et al. Pimentas do gênero Capsicum no Brasil. 2006.

DE FREITAS, M. C. et al. Acute capsaicin supplementation improves 1,500-m running time-trial performance and rate of perceived exertion in physically active adults. The Journal of Strength & Conditioning Research, v. 32, n. 2, p. 572–577, 2018a.

DE FREITAS, M. C. et al. Acute capsaicin supplementation improves resistance training performance in trained men. The Journal of Strength & Conditioning Research, v. 32, n. 8, p. 2227–2232, 2018b.

DE FREITAS, M. C. et al. Acute capsaicin supplementation improved resistance exercise performance performed after a high-intensity intermittent running in resistance-trained men. The Journal of Strength & Conditioning Research, v. 36, n. 1, p. 130–134, 2022.

DONG, Jin-Guo. The role of heart rate variability in sports physiology. Experimental and therapeutic medicine, v. 11, n. 5, p. 1531-1536, 2016.

DRAKE, D.; KENNEDY, R.; WALLACE, E. Familiarization, validity and smallest detectable difference of the isometric squat test in evaluating maximal strength. Journal of sports sciences, v. 36, n. 18, p. 2087-2095, 2018.

ESFORMES, J.I.; BAMPOURAS, T.M. Effect of back squat depth on lower-body postactivation potentiation. The Journal of Strength & Conditioning Research, v. 27, n. 11, p. 2997-3000, 2013.

FISCHER, M. J. M.; CIOTU, C. I.; SZALLASI, A.. The mysteries of capsaicin-sensitive afferents. Frontiers in Physiology, v. 11, p. 554195, 2020.

FONSECA, I.C.S. et al. Subsequent performance of two 1RM tests in the same session reduces 1RM and consequently the volume load of strength training session. Journal of Exercise Physiology online, v.23, n.5, p.65-75, 2020.

FOSHATI, S. et al. Short-and long-term effects of capsaicin supplementation on glycemic control: A systematic review and meta-analysis of controlled trials. Food & Function, v. 12, n. 12, p. 5236-5246, 2021.

GEOVANINI, G. R. et al. Age and Sex Differences in Heart Rate Variability and Vagal Specific Patterns – Baependi Heart Study. Global Heart, v. 15, n. 1, 21 out. 2020.

GRGIC, J. et al. Effects of Capsaicin and Capsiate on Endurance Performance: A Meta-Analysis. Nutrients, v. 14, n. 21, p. 4531, 2022.

GROSSMAN, S. C.; MATTSON PORTH, C. Porth fisiopatología: alteraciones de la salud; conceptos básicos. [s.l.] Wolters Kluwer, 2016.

GUEST, N. S. et al. Sport nutrigenomics: Personalized nutrition for athletic performance. Frontiers in Nutrition, v. 6, 19 fev. 2019.

HSU, Y.-J. et al. Capsaicin supplementation reduces physical fatigue and improves exercise performance in mice. mdpi.com, 2016.

IWAI, K.; YAZAWA, A.; WATANABE, T. Roles as metabolic regulators of the non-nutrients, capsaicin and capsiate, supplemented to diets. Proceedings of the Japan Academy, Series B, v. 79, n. 7, p. 207–212, 2003.

JAMALI, H. K.; WAQAR, F.; GERSON, M. C. Cardiac autonomic innervation. Journal of Nuclear Cardiology, v. 24, n. 5, p. 1558–1570, 1 out. 2017.

JIANG, Z. et al. Lipid-Lowering Efficacy of the Capsaicin in Patients With Metabolic Syndrome: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. Frontiers in Nutrition, v. 9, 2022.

JORGENSEN, C.; DOMENE, C. Location and character of volatile general anesthetics binding sites in the transmembrane domain of TRPV1. Molecular pharmaceutics, v. 15, n. 9, p. 3920–3930, 2018.

KAWADA, Teruo et al. Gastrointestinal absorption and metabolism of capsaicin and dihydrocapsaicin in rats. Toxicology and applied pharmacology, v. 72, n. 3, p. 449-456, 1984.

KONO, Y. et al. Effects of oral stimulation with capsaicin on salivary secretion and neural activities in the autonomic system and the brain. Journal of Dental Sciences, v. 13, n. 2, p. 116–123, 2018.

KUSS, O. et al. Time domain parameters can be estimated with less statistical error than frequency domain parameters in the analysis of heart rate variability. Journal of electrocardiology, v. 41, n. 4, p. 287–291, 2008.

LEBOVITZ, E. E. et al. Positive allosteric modulation of TRPV1 as a novel analgesic mechanism. Molecular Pain, v. 8, p. 1744–8069, 2012.

LIMA, L. S. L. Estudo socioeconômico da pimenta malagueta na região sudoeste da Bahia. 2012. Dissertação [Mestrado] - Universidade Estadual do Sudoesteda Bahia, Vitória da Conquista, 2012.

LUDY, M.J.; MOORE, G. E.; MATTES, R. D. The effects of capsaicin and capsiate on energy balance: critical review and meta-analyses of studies in humans. Chemical senses, v. 37, n. 2, p. 103–121, 2012.

LUDY M.J; MATTES, R.D. The effects of hedonically acceptable red pepper doses on thermogenesis and appetite. Physiol Behav. Mar 1;102(3-4):251-8, 2011.

LUO, Z. et al. TRPV1 activation improves exercise endurance and energy metabolism through PGC-1α upregulation in mice. Cell research, v. 22, n. 3, p. 551-564, 2012.

MAKIVIĆ, B.; NIKIĆ DJORDJEVIĆ, M.; WILLIS, M. S. Heart Rate Variability (HRV) as a tool for diagnostic and monitoring performance in sport and physical activities. Journal of Exercise Physiology Online, v. 16, n. 3, 2013.

MICHAEL, S.; GRAHAM, K. S.; DAVIS, G. M. Cardiac autonomic responses during exercise and post-exercise recovery using heart rate variability and systolic time intervals—a review. Frontiers in physiology, v. 8, p. 301, 2017.

MINERS, J. O.; BIRKETT, D. J. The use of caffeine as a metabolic probe for human drug metabolizing enzymes. General pharmacology, v. 27, n. 2, p. 245–249, 1996.

MOMAYA, A.; FAWAL, M.; ESTES, R. Performance-Enhancing Substances in Sports: A Review of the Literature. Sports Medicine, v. 45, n. 4, p. 517–531, 2015.

MONSEREENUSORN, Y. et al. Capsaicin - a literature survey. Critical Reviews in Toxicology, v. 10, n. 4, p. 321–339, 1982.

MOUROT, L. et al. Decrease in heart rate variability with overtraining: assessment by the Poincare plot analysis. Wiley Online Library, v. 24, n. 1, p. 10–18, 2016.

MOYA-RAMON, M. et al. Validity and reliability of different smartphone applications to measure HRV during short and ultra-short measurements in elite athletes. Computer Methods and Programs in Biomedicine, v. 217, p. 106696, 2022.

O'NEILL, J. et al. “Unravelling the mystery of capsaicin: a tool to understand and treat pain.” Pharmacological reviews vol. 64,4: 939-71, 2012.

PICONI, B. S. et al. Suplementação de capsaicina e o desempenho de mulheres no Crossfit®. Coleção Pesquisa em Educação Física, Várzea Paulista, v. 18, n. 04, p. 117–126, 2019.

PLEWS, D. J. et al. Training adaptation and heart rate variability in elite endurance athletes: Opening the door to effective monitoring. Sports Medicine, v. 43, n. 9, p. 773–781, set. 2013.

ROSSI, P. A. Q et al. Acute response to capsiate supplementation at rest and during exercise on energy intake, appetite, metabolism, and autonomic function: a randomized trial. Journal of the American Nutrition Association, v. 41, n. 6, p. 541-550, 2022.

SALVADOR, L.S. et al. Agonist- and Ca2+-dependent desensitization of TRPV1 channel targets the receptor to lysosomes for degradation. The Journal of biological chemistry vol. 287,23, 2012.

SHIN, K. O.; MORITANI, T. Alterations of autonomic nervous activity and energy metabolism by capsaicin ingestion during aerobic exercise in healthy men. Journal of nutritional science and vitaminology, v. 53, n. 2, p. 124–132, 2007.

SHIN, K. O.; MORITANI, T. Capsaicin supplementation fails to modulate autonomic and cardiac electrophysiologic activity during exercise in the obese: with variants of UCP2 and UCP3 polymorphism. Journal of Sports Science & Medicine, v. 7, n. 3, p. 365, 2008.

SHIN, K. O.; YEO, N. H.; KANG, S.. Autonomic nervous activity and lipid oxidation post exercise with capsaicin in the humans. Journal of Sports Science & Medicine, v. 9, n. 2, p. 253, 2010.

SIMÕES, C. B. et al. Acute caffeine and capsaicin supplementation and performance in resistance training. Motriz: Revista de Educação Física, v. 28, 2021.

SNITKER, S. et al. Effects of novel capsinoid treatment on fatness and energy metabolism in humans: possible pharmacogenetic implications. The American journal of clinical nutrition, v. 89, n. 1, p. 45-50, 2009.

TRIPOSKIADIS, F. et al. The sympathetic nervous system in heart failure: physiology, pathophysiology, and clinical implications. Journal of the American College of Cardiology, v. 54, n. 19, p. 1747–1762, 2009.

VANDERLEI, L. C. M. et al. Noções básicas de variabilidade da frequência cardíaca e sua aplicabilidade clínica. Brazilian Journal of Cardiovascular Surgery, v. 24, p. 205–217, 2009.

WEIR, J.P. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM.The Journal ofStrength & Conditioning Research, v. 19, n. 1, p. 231-240, 2005.

ZALESKI, K. S. et al. Sex differences in estimates of cardiac autonomic function using heart rate variability: effects of dietary capsaicin. European Journal of Applied Physiology, p. 1–10, 2023.

ZHANG, W. et al. The effects of capsaicin intake on weight loss among overweight and obese subjects: a systematic review and meta-analysis of randomized controlled trials. British Journal of Nutrition, p. 1-12, 2023.