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Health Problems of Police Officers in Brazil That Arise in The Performance of Their Work

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Abstract

This article examines the effects of a heart rate variability biofeedback protocol on self-regulation and performance indicators in Brazilian police officers. The biofeedback protocol lasted for five days and was combined with operational training. Participants were preselected and divided into two groups: control group (26 officers) and treatment group (26 officers). The study assessed all participants before and after the intervention, measuring their self-regulation (maximum heart rate) and performance (procedures and response time) in a controlled environment that simulated an armed reaction situation. Significant effects were observed in the treatment group, aligning with the hypothesized direction. There was a decrease in maximum heart rate, indicating self-regulation, as well as a reduction in procedural failures and response time, indicating enhanced performance. The findings suggest that exclusive reliance on police training may be insufficient for enhancing performance. Instead, the ability to promote self-regulation through heart rate variability biofeedback emerges as a crucial factor. The purpose of the research was to gather evidence for public policy implementation in the city of Barueri, state of São Paulo, Brazil. While the protocol has successfully met its intended objectives, it is imperative to control some logistical and technological limitations prior to implementing the protocol as public policy.

Keywords: Heart rate variability biofeedback, Self-regulation, Police performance, Lethal force, Acute stress

1. Introduction

One of the primary challenges in police organizations is to adequately prepare front-line officers to appropriately use force, particularly at lethal levels. Poor police performance can result in the misuse of force and unjustifiable deaths. In response to this issue, police organizations often invest in training programs aimed at enhancing the knowledge and skills of their officers. Despite the advocacy from scholars and reformers for such investments, there is limited understanding regarding the effectiveness of training in improving police performance on duty [1]. Without evidence demonstrating the efficacy of training, the cycle of low performance and subsequent training persists, failing to effectively address the root problem of unjustifiable deaths.

Research on the relationship between police training and performance is still in its early stages, partially due to the inherent challenges of conducting studies within police organizations. Studies conducted with American and Brazilian police officers have revealed that training alone does not yield the expected changes in police behavior during job [2,3]. The critical issue lies in the fact that police training primarily emphasizes technical, tactical, and physical aspects while neglecting the impact of psychophysiological stress [4]. Consequently, although training holds significance, it is insufficient to bring about the desired behavioral changes.

To address this research gap, the current study investigates the impact of a Heart Rate Variability Biofeedback (HRVB) protocol on self-regulation and performance in police officers. The hypothesis posits that physiological modulation during acute stress situations can enhance police response to risk and improve overall performance. The HRVB protocol was implemented as part of a five-day training program in conjunction with standard training in a pilot project led by the Secretariat of Urban Security and Social Defense of the city of Barueri, state of São Paulo, Brazil. The aim of this pilot project was to gather empirical evidence to support the implementation of a policy aimed at enhancing police performance.

Extensive scholarly literature demonstrates that the exposure of police officers to dangerous situations elicits a sympathetic nervous system response, resulting in a state of arousal. This physiological response is evident through heightened heart rate, increased cortisol release, and various other physiological alterations [5-7]. The organismic reaction to stressful stimuli plays a pivotal role in safeguarding the well-being of police officers [8].

When maintained at moderate levels, this state of arousal contributes to establishing an optimal level of vigilance, concentration, and enhancement in cognitive functioning. It serves to optimize both the formation and retrieval of memory, alongside expanding sensory perception, thereby augmenting the capacity to effectively address threats [9,10].

However, when this elevation exceeds a markedly high threshold, it impairs cognitive function, hindering access to knowledge stored in memory, and compromises motor, leading to heightened errors and diminished accuracy [10-12]. Grossman and Christensen (2012) propose that this decline initiates when the heart rate falls within the range of 145 bpm to 175 bpm (beats per minute), yet they underscore the impracticality of establishing this range as a universal measurement [10].

Under such conditions, it is highly probable that, for instance, following a pursuit of a stolen vehicle, a police officer may encounter challenges in exiting from the vehicle, experience a loss of lateral visual acuity (referred to as tunnel vision), thereby impeding the perception of surrounding events. Unintentional lapses in adhering to well-established operational procedures, which enhance both personal and third-party safety, may occur. Improper firearm positioning is another potential outcome, among other behaviors incongruent with the acquired knowledge from operational training. However, this predicament may exacerbate if the heart rate surpasses 175 bpm, potentially resulting in the officer collapsing [10].

Among the limited studies presenting empirical evidence of police stress during duty, it was observed that the maximum heart rate reached 171 bpm during physical confrontation, and 165 bpm during a stopping to the vehicle of a driver suspected of drug use [13,14]. The findings from the study conducted by Anderson, Litzenberger, and Plecas reveal that identifying the presence of a suspect or merely suspecting their presence elicits a similar physiological response, whether the police officer is in the process of opening the holster (108 bpm) or has a firearm in hand (111 bpm) [13].

In the late 1990s, HRVB was introduced as a technique to regulate the psychophysiological responses of police officers [15]. HRVB works by activating the parasympathetic nervous system, which counteracts the arousal caused by the sympathetic nervous system, thereby promoting balance in the autonomic nervous system. Through biofeedback training, officers acquire self-regulation skills that can enhance their performance. Empirical studies have consistently demonstrated the effectiveness of HRVB, leading to its widespread adoption by police academies in various countries [16-19].

Biofeedback training provides individuals with feedback on their internal physiological processes and offers guidance on how to modify them [18]. While different HRVB protocols and devices exist, they all share a common principle of slow and deep breathing, typically at a rate of 4 to 7 breaths per minute. This respiratory pattern increases the magnitude of heart rate fluctuations, reaching a peak at 0.1 Hz, which corresponds to achieving cardiac coherence or internal balance [20]. Acquiring the ability to synchronize breathing with this rhythm empowers individuals to promote self-regulation.

This study endeavors to examine the impacts of a HRVB training protocol on self-regulation and performance, assessed through maximum heart rate, procedural effectiveness, and response time.

The primary hypothesis formulated is as follows:

H0: The HRVB protocol will not yield any significant effects or may have negative effects on self-regulation and performance.
This hypothesis will be tested against the alternative hypothesis:
HA: The HRVB protocol will yield positive effects on self-regulation and performance.

2. Method

2.1. Sample

The current study focuses on police officers who work on the front line in Brazil, with participants selected from the cities of Barueri and Carapicuíba in the Metropolitan Area of São Paulo. The police officers were chosen from those who had taken part in police training organized by the Secretariat of Urban Security and Social Defense of Barueri during the first and third weeks of September 2022. There were 26 participants in each week, with police managers carefully selecting and distributing the participants to minimize disruption to policing activities. As the number of trainees was low, all 52 participants were included in the study, with those from week 1 forming the control group and those from week 2 forming the treatment group.

The average age of the participants was 44 years, and they had an average of 15 years of service. The majority of the participants were male (96.2%), non-white (67.3%), married (78.8%), and had children (76.9%). More than half of the participants had higher education (59.6%). While none of the participants reported heart problems or the use of medications such as antidepressants, anxiolytics, or tranquilizers, the majority of the group was overweight (80.8%). Most of the participants did not smoke cigarettes (81.6%), but almost 90% were consumers of alcohol.

The study used data collected by the Operational Police Stress Questionnaire – PSQ-Op to identify the primary stressors experienced by police officers [21]. The results showed that the risk of being injured on duty and tiredness were the two main stressors of policing activity. The norms and cut-off values of this instrument indicated that the level of operational stress of the sample participants was quite pronounced, with most reporting high (39%) or moderate (45%) stress levels, and only a small proportion reporting low stress levels (16%) [22].

Regarding the use of firearms, 40.4% of the participants had already fired shots while on duty, and in most cases (72%), this practice occurred in only one or two events. Those who used firearms were mostly more experienced (71% with over 20 years of service) and older (86% over 40 years of age). None of the novices (those with less than six years of service) used a firearm during policing.

The study sample is not representative of the broader population of interest, and the generalizability of the findings is constrained by the non-random nature of the sample selection process. Nonetheless, the primary objective of this study was to evaluate the efficacy of a heart rate variability biofeedback protocol in a similar real-world context. The observed effects of protocol in this study can serve as a valuable reference for informing the formulation of a public policy targeted at enhancing police performance in acute stress situations.

2.2. Measures

The criterion for measuring self-regulation in this study was the maximum heart rate (HR_{MAX}), which has been shown to be a reliable indicator of the level of arousal resulting from exposure to stressors. Higher HR_{MAX} values have been associated with impaired cognitive and motor functioning. The present study hypothesized that HRVB would decrease HR_{MAX}, indicating improved balance in the autonomic nervous system, which could potentially enhance performance (*Self-regulation* = HR_{MAX}).

This measurement was performed during firearm exercises in a controlled environment, both before and after the HRVB training. Participants wore a Polar H10 heart monitor with a chest strap, and the data was recorded using the Elite HRV app and analyzed using Kubios HRV Standard 3.5.0 software.

In this study, the performance construct was defined as the sum of two other constructs: procedure (P) and time (T). P represents an individual measure of the extent to which participants followed the prescribed procedures during the exercise, whereas T measures the response time of the team of four police officers occupying the patrol car.

Given that all participants received prior training on the exercise procedures, adherence to the prescribed procedures serves as an indicator of knowledge recall from memory. Additionally, completing the exercise within a specified time frame (up to 30 seconds) is indicative of successful coordination of motor skills and procedure execution. Therefore, the performance construct in this study was calculated as the sum of the P and T scores (*Performance* = P + T).

The Procedure (P) in this study comprises the measures of safe conduct (P_{COND}) and firearm position (P_{GUN}). The instructor, an expert in firearms training, identified ten safe behaviors (as presented in Table 1) that were to be followed to achieve the expected performance. The procedures were evaluated as either present (0) or absent (1). The final P_{COND} score was calculated as the sum of all the points. The performance of each participant was captured on video, and later, the expert reviewed the footage to validate the results.

	Safe conduct constructs
1	Position of the first shot sequence
2	Move to cover point
3	Position at the cover point
4	Change of chargers
5	Return to the patrol car
6	Position of the weapon
7	Alert voice
8	Cover voice
9	Adjustments of the equipment
10	Delivery of the firearm at the end of the exercise

Table 1: Safe conduct - P_{COND}

Note: Participants were trained how to perform each conduct, it means, they knew "when", "how", and "what" to do in the different stages of the simulation. The assessment sought to identify whether they performed what they learned.

In terms of firearm position procedures (Table 2), the measurement was conducted in a similar manner: either present (0) or absent (10) was recorded. However, in this case, 10 points were allocated to each missing procedure. The P_{GUN} score was calculated as the sum of all points obtained for this construct.

	Firearm position constructs
1	Firearm pointed at ground or target only
2	Finger off trigger before firing
3	Open firearm at the end of the exercise

Table 2: Firearm position – P_{GUN}

Note: These constructs are golden rules in the use of firearms.

This metric was created to measure the occurrence of "failure". As such, any score other than zero indicates that some procedure was not followed, and the firearm was positioned improperly. Failure to follow safety procedures can lead to unjustifiable deaths, but failure in the weapon position is even more critical. Thus, we defined P as the sum of scores for both safe conduct and weapon position ($P = P_{COND} + P_{GUN}$).

The construct of time (T) is a composite score consisting of two parts: the value of time spent (T_{VALUE}) to complete the exercise and the points (T_{POINT}) assigned according to the scale presented in Table 3 ($T = T_{VALUE} + T_{POINT}$).

	T_{VALUE}	T_{POINT}
1	Up to 30 seconds	0
2	From 31 to 35 seconds	10
3	From 36 to 40 seconds	20
4	From 41 to 45 seconds	30
5	From 46 to 50 seconds	40
6	More than 50 seconds	50

Table 3: Score scale of time – T

After conducting the test, the expert determined that the optimal time to complete the exercise was 30 seconds or less (T_{VALUE}), and that no points would be added or subtracted from this time (T_{POINT}). Thus, the best possible score for time (T) would be less than or equal to 30. Any score greater than 30 would indicate a slower response time, and the higher the score, the more severe the negative impact on motor skills.

To register the time taken to perform the exercise, we used a chronometer that was started when the signal announced the beginning of the exercise and stopped when the last participant in the team closed the door of the patrol car. The same device was used in all evaluation stages and the measure of time (T) was consolidated by observing the recorded videos.

2.3. Design

In this study, we employed a quasi-experimental design with two pre- and post-test groups [23]. In notation form, it can be represented as:

$$\begin{array}{cccc} N & O & & O \\ N & O & X & O \end{array}$$

Where:
N = groups were non-equivalent
O = the five measures (HR_{MAX}; P_{COND}; P_{GUN}; T_{VALUE}; and T_{POINT})
X = heart rate variability biofeedback protocol

The design of non-equivalent groups is one of the most commonly used in social research. The main characteristic of this design is non-randomization, which is why the groups are referred to as non-equivalent. As a result, there may be some initial differences between the groups, which can pose a threat to internal validity and potentially impact the results.

Characteristics	Control Group	Treatment Group
City of Barueri (n)	17	19
City of Carapicuíba (n)	8	7
Average age	42.5	45.7
Average service time	14.1	16.9
%Overweight	61.5	61.5
%Low level of operational stress	23.1	8.0
%Moderate level of operational stress	42.3	48.0
%High level of operational stress	34.6	44.0

Table 4: Distribution of key characteristics between groups

Note: These data were collected through a self-reported questionnaire.

The sample possesses certain crucial characteristics that may adversely impact the results if the distribution between the groups is uneven. One of these characteristics pertains to the participants' city of origin, as each municipality may adhere to distinct protocols when selecting police officer candidates, and the urban environment can exhibit considerable variation. However, the data presented in Table 4 demonstrates that the distribution by city is homogeneous between the control and treatment groups. Similarly, there is no discernible disparity in age, length of service, or overweight between the two groups. Notably, age and overweight can exert a substantial influence on the self-regulation outcomes, whereas length of service may impact performance.

However, there is a significant difference in the distribution of operational stress levels between the two groups. Specifically, the control group has a higher proportion of participants with low levels of stress compared to the treatment group, where a greater frequency of individuals exhibits high levels of operational stress. As for the moderate level of operational stress, it appears to be evenly distributed across both groups. We will revisit this dissimilarity in the analysis of the findings.

Intervention: Five-Day Heart Rate Variability Biofeedback Protocol

Both groups attended five days of procedural and technical training (P&T), however the HRVB protocol was administered only to the treatment group. Self-regulation and performance measures (HR_{MAX}, P_{COND}, P_{GUN}, T_{VALUE}, and T_{POINT}) were collected from both groups, pre- and post-intervention (Table 5).

On the afternoon of day 1, the treatment group commenced the initial stages of the HRVB protocol with a lecture that elucidated the physiological changes that occur when faced with stressful stimuli. The lecture also emphasized the impact of these changes on police performance and underscored the importance of self-regulation during acute stress events. Following the lecture, participants were introduced to the HRVB practice. They were highly receptive to the new knowledge, as it helped them understand their prior experiences better. They acknowledged that this was the first instance where they encountered a "humanized approach" to police work.

	Control Group (1st week of Sep 22)			**Treatment Group (3rd week of Sep 22)**		
	Day 1	Day 2-4	Day 5	Day 1	Day 2-4	Day 5
Morning	Pre intervention	P&T	Post intervention	Pre intervention	HRVB ^{b} P&T	Post intervention
Afternoon	P&T	P&T		HRVB ^{a}	HRVB ^{b} P&T	

Table 5: Control and Treatment Group Training Calendar

Note: P&T = Procedural and Technical Training
[a] Theoretical and practical introduction of HRVB
[b] 30-minute HRVB exercise session

From day 2 to 4, there were two 30-minute HRVB practice sessions each day, one in the early morning and another in the afternoon. Due to budgetary limitations, only one HRVB device (cardioEmotion®) was available, and participants engaged in group practice in a classroom setting. One participant sat in front of the computer, plugged in the sensor, and commenced the HRVB training, with the tracking pacer set to 5.5 breaths per minute. The computer screen was projected onto a large screen so that other police officers could participate in the HRVB training from their seats and regulate their breathing to achieve heart coherence.

Participants took turns at the device every ten minutes. On the final day of the intervention, participants had the opportunity to engage in ten minutes of individual practice and three hours of group practice. The fifth day was the post-intervention phase, during which participants practiced ten minutes the breathing techniques before undergoing the performance evaluation.
Research Procedures.

We selected the second-week group as the treatment group to prevent cross-contamination. Proximity to individuals in heart coherence is sufficient to induce changes towards internal balance. Therefore, we collected the five measures of the control group corresponding to the pre- and post-intervention before introducing the five-day HRVB protocol to the treatment group.

The HRVB five-day protocol trial was a pilot project aimed at collecting evidence that would support public policy. Consequently, the protocol would be extended to all police officers in the city of Barueri, which is approximately six hundred. All participants were informed about this initiative, its objectives, and research activities, and ensured confidentiality. They all acknowledged the significance of the Executive's initiative and conveyed their appreciation. After the research, participants in the control group also received the HRVB protocol.

The measurements were obtained within a simulated scenario replicating an armed reaction situation, which elicited an elevation in heart rate as a physiological response to the perceived threat of mortality. All participants were knowledgeable about the prescribed procedures (refer to Table 1 and 2) to be followed, as they had undergone prior training in this regard.

The evaluation began with four police officers inside an SUV patrol car, halted in front of six paper targets, four of which were to be shot and two not to be shot. They initiated the group action after the signal. Each officer had to fire ten shots, change the charger among shots, verbalize, and protect themselves and their partners. The test concluded when everyone was back inside the patrol car.

Each group consisted of four members, and the participants could choose their group. We respected the affinities among them because well-coordinated actions depend on the connection among group members. Considering that the number of participants in both groups was not a multiple of four, the last team was completed with other participants who had already performed, without altering the previously collected measures.

There was an observer for each participant, and another was responsible for the chronometer. The expert trained them to collect the measures. They were all staff of the Secretariat for Urban Security and Social Defense. At the end of the test, each participant received the results and signed the evaluation form, which was the instrument used to record the measures. We did not create measures of decision-making because the participants knew how many shots they should fire, and which targets they should shoot and which they should not.

We also did not measure accuracy because they used a firearm without bullets in the pre-test.

As a consequence of budget constraints at the municipal level and the expense associated with ammunition, the participants were only allowed to discharge their firearms using live ammunition during the post-intervention phase. It is important to acknowledge that this particular aspect of the experiment has the potential to influence the outcomes of the self-regulation indicator. We will revisit this topic in the results section for further examination and analysis.

As for cardiac monitoring, each participant wore a Polar H10 chest strap, which was paired with the Elite HRV app, to read heart rate data. At the end of the exercise, the participants were instructed to export the data, which were later analyzed using the Kubios HRV Standard 3.5.0 software, which provided the maximum heart rate measurement.

Results

In this study, the final sample of police officers was reduced from 52 to 51 as one officer was summoned to court on the day of the post-test. The study assessed the performance of all 51 participants using four measures: P_{COND}, P_{GUN}, T_{VALUE}, and T_{POINT} in both pre- and post-test. However, complete data regarding the measure of self-regulation (HR_{MAX}) could not be obtained for all participants due to certain officers failing to successfully connect the heart rate monitor with the Elite HRV app. Consequently, HR_{MAX} data was only collected from a total of 17 participants in the control group and 13 participants in the treatment group. Unfortunately, this discrepancy could not be rectified as the data collection process occurred in real-time.

In the pre-test, the control group exhibited a much lower maximum heart rate (120.9 bpm) compared to the treatment group (130.7 bpm). However, after using live ammunition in the post-test, the control group's heart rate increased by 22.2% (147.7 bpm), whereas the treatment group's heart rate only increased by 8.3% (141.5 bpm) (Table 6).

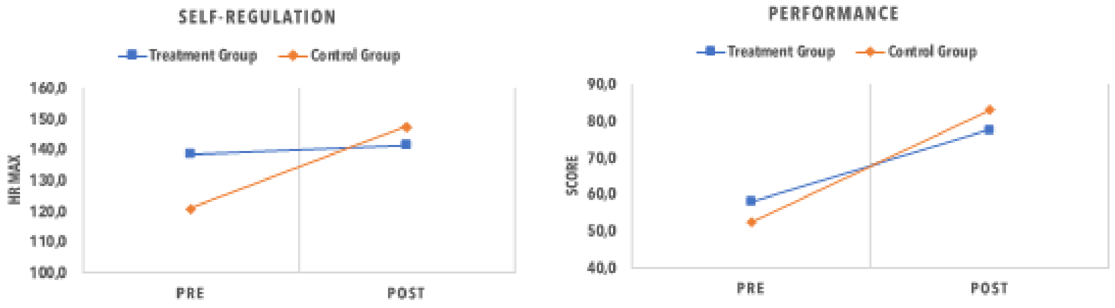

Figure 1: Pre- and post-test means of treatment and control groups for the two variables

		Self-Regulation			Performance		
		Pre	Post	Gain	Pre	Post	Gain
Treatment	Mean	138.7	141.5	-2.8	58.1	77.7	-19.6
	SD	18.6	14.1	4.5	22.3	17.3	5.0
	N	13	13		52	52	
Control	Mean	120.9	147.7	-26.8	52.5	83.2	-30.7
	SD	23.5	23.5	0.0	12.4	21.7	-9.3
	N	17	17		51	51	

Table 6: Means, standard deviations, and sample sizes (n) for pre-test, post-test, and gain scores of the two variables

Note: SD = Standard Deviation

A similar trend was observed in the performance variable, where the control group's pre-test score (52.5) indicated fewer procedural failures and shorter response time than the treatment group's score (58.1). In the post-test, both groups exhibited worsened performance, but the treatment group's performance declined less (77.7) compared to the control group (83.2). Based on these findings, we can infer at least three things. Firstly, the armed reaction simulation exercise triggered the expected physiological response of increased heart rate. This result indicates that a spontaneous physiological response to a stressor stimulus occurs, and the physiological change can be more intense when using live ammunition.

Secondly, the study found that there is no perfect performance in the face of the risk of death. The best possible performance score would be equal to or less than 30, corresponding to no procedural failure and a response time of up to 30 seconds. Although some participants in both groups scored below 30 in the pre-test (around 10% of the group), all scores in the post-test were above 30.

Finally, the results suggest that there was a positive effect of HRVB training. However, the means of the treatment group did not drop after the intervention, as expected, and the negative value of the average gain indicated an upward trend opposite to that expected. The initial difference between the groups and the increase in the post-test represent threats to internal validity, and these threats need to be controlled to determine the effect of heart rate variability biofeedback.

Initial Between-Group Difference

Although the groups were not selected randomly, we previously noted that their key characteristics were quite similar, with the exception of the level of operational stress (see Table 4). The control group exhibited a lower level of operational stress, whereas the treatment group had a higher level. This unequal distribution of the stress level likely explains why the control group scored better in the pre-test for both variables.

If we control for the effect of operational stress, we would expect the means of the control and treatment groups to be equal in the pre-test ($Y_0^C = Y_0^T$). Hence, the disparity observed in these outcomes can be attributed to operational stress ($Stress = Y_0^T - Y_0^C$).

The operational stress component should be subtracted from the mean values of both self-regulation and performance indicators in the pre- and post-test measurements of the treatment group ($Y_0^{TS} = Y_0^T - Stress$; $Y1^{TS} = Y1^T - Stress$).

Where:
Y_0^C = Mean of the control group in the pre-test
Y_1^C = Mean of the control group in the post-test
Y_0^T = Mean of the treatment group at pre-test
Y_1^T = Mean of the treatment group at post-test
Y_0^{TS} = Mean of the treatment group at pre-test adjusted by operational stress
Y_1^{TS} = Mean of the treatment group at post-test adjusted by operational stress

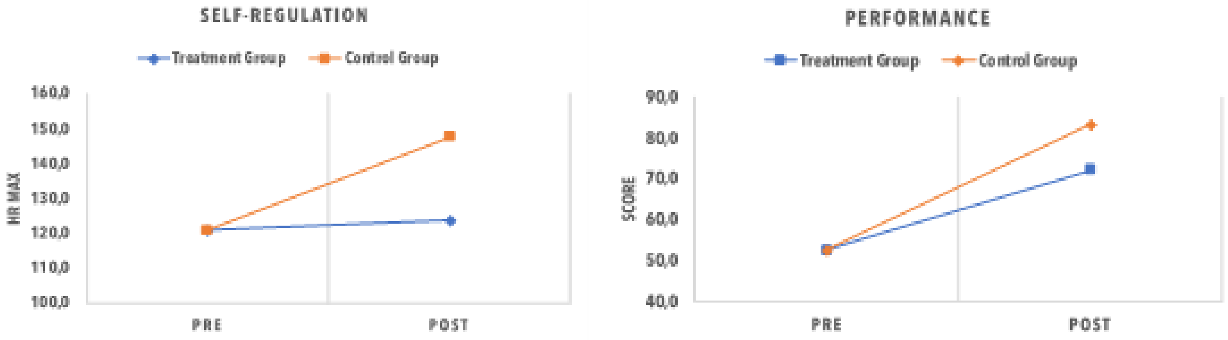

Figure 2: Initial between-group difference adjustment: mean of pre- and post-test for experimental and control groups in relation to the two variables

		Self-Regulation			**Performance**		
		Pre	**Post**	**Gain**	**Pre**	**Post**	**Gain**
Treatment	**Mean**	**120.9**	**123.7**	**-2.8**	**52.5**	**72.1**	**-19.6**
	SD	**18.6**	**14.1**	**4.5**	**22.3**	**17.3**	**5.0**
	N	**13**	**13**		**52**	**52**	
Control	**Mean**	**120.9**	**147.7**	**-26.8**	**52.5**	**83.2**	**-30.7**
	SD	**23.5**	**23.5**	**0.0**	**12.4**	**21.7**	**-9.3**
	N	**17**	**17**		**51**	**51**	

Table 7: Initial between-group difference adjustment: means, standard deviations, and sample sizes (ns) for pre-test, post-test, and gain scores of both variables

Increase in Post-Test Scores

After adjusting for the initial difference between groups, the next step is to control the potential threat of increased results in the post-test. We hypothesize that the use of firearms with live ammunition during the post-test is the factor that accounts for this increase. The pre-test results for both groups were lower because the firearms were used without live ammunition.

If we control for the effect of shooting with bullets, we would expect the means of the control group in both the pre- and post-test to be the same, as this group did not receive the treatment ($Y_0^C = Y_1^C$). Hence, the observed discrepancy in these outcomes can be attributed to the effect of using live ammunition during shooting exercises ($Bullet = Y_1^C - Y_0^C$).

The effect attributable to the use of live ammunition must be subtracted from the mean value obtained in the post-test for both self-regulation and performance indicators, when comparing the control group and the treatment group ($Y_1^{CA} = Y_1^{C} - Bullet$; $Y_1^{EA} = Y_1^{E} - Bullet$).

Where:
Y_1^{CA} = Mean of the control group at post-test adjusted by the bullet
Y_1^{EA} = Mean of the treatment group at post-test adjusted by the bullet

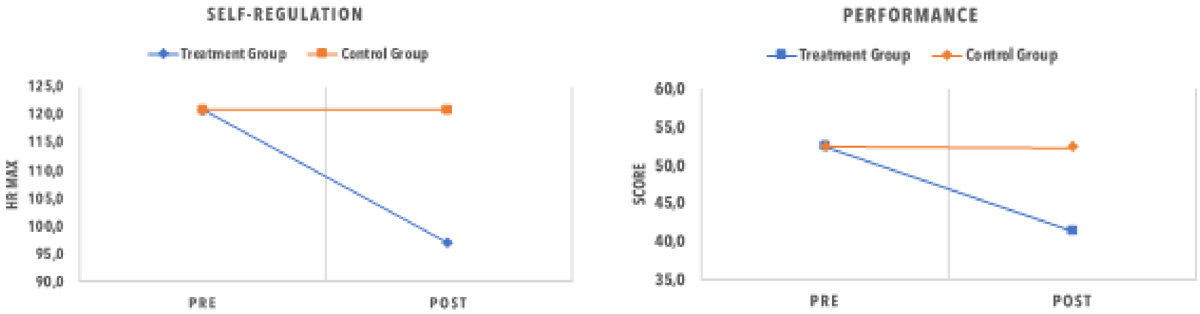

Figure 3: Post-test increase adjustment: mean pre- and post-test for experimental and control groups in relation to the two variables

		Self-Regulation			Performance		
		Pre	Post	Gain	Pre	Post	Gain
Treatment	Mean	120.9	96.9	24.0	52.5	41.4	11.1
	SD	18.6	14.1	4.5	22.3	17.3	5.0
	N	13	13		52	52	
Control	Mean	120.9	120.9	0,0	52.5	52.5	0.0
	SD	23.5	23.5	0,0	12.4	12.4	0.0
	N	17	17		51	51	
F =		19.988	p<0.001		p<0.037		

Table 8: Adjusted results: Means, standard deviations, and sample sizes (ns) for pre-test, post-test, and gain scores of both variables, and f-test for difference between mean gains

After controlling for threats to internal validity, the descriptive analysis demonstrates that the treatment group experienced a positive gain, while the control group remained stable (Table 8). Specifically, the mean values suggest that the group receiving the HRVB protocol demonstrated a decrease in maximum heart rate, indicating improved self-regulation, as well as a reduction in procedural failures and response time, which collectively correspond to enhanced performance. These findings are more clearly depicted in Figure 3.

In terms of inferential statistical analysis, an examination of the self-regulation and performance variables revealed an asymmetrical distribution, prompting their independent consideration. Additionally, owing to the limited number of participants in the sample, comparisons were conducted based on positions. Subsequently, to assess the disparities between the control and treatment groups post-intervention, the non-parametric Repeated Measures Analysis of Variance (ANOVA-RM) model was employed. The Friedman test substantiated the significant difference between the groups, both for the self-regulation variable [F(1) = 19.988; p < 0.001] and performance [F(1) = 4.350; p = 0.037]. Consequently, it becomes evident that, in both instances, the alternative hypothesis must be embraced, signifying that the expectations have been met.

Limitations

No analogous studies involving public security agents in Brazil were identified. Hence, this constitutes a pioneering endeavor in the country, successfully assembling objective evidence of the favorable impact of biofeedback on police performance in acute stress situations. This pilot project, therefore, holds the potential to inform the development of public policy; nonetheless, the efficacy of the policy implementation is contingent upon addressing certain limitations. These limitations predominantly stem from logistical and technological factors.

Regarding the first issue, the acquisition of self-regulation and performance metrics necessitated tests involving live ammunition conducted on a shooting range. This approach incurs financial expenses and, notably, exerts a detrimental influence on law enforcement operations due to the time-intensive nature of the practice. From a managerial standpoint, these considerations may pose a bottleneck to policy implementation and serve as a hindrance to effective execution.

Nevertheless, the primary limitations are rooted in the technological domain, specifically concerning the electronic devices employed for cardiac monitoring and biofeedback exercises. Findings indicate that recording the heart rate of all participants proved challenging, primarily due to difficulties in synchronizing the Polar H10 heart rate monitor with the Elite HRV app. Despite the commendable quality of both the product and app, this outcome underscores the imperative to reconsider the selection of technological devices for cardiac monitoring.

Concerning cardioEmotion®, the decision to conduct biofeedback exercises in group settings was influenced by the device's elevated cost and the constrained budget allocated to the project. At the time of the study, no alternative electronic device was identified in the national market, and international options were deemed financially prohibitive due to additional Brazilian import taxes. Additionally, during the evaluation of the HRVB protocol, only the Home version of cardioEmotion® was available, designed exclusively for non-professional and non-research applications. Consequently, its functionalities are limited, lacking the capacity to record heart rate variability data, restricted compatibility to computers with a Windows operating system, and an absence of data export capabilities. Despite its utility for biofeedback exercises, the utilization of this device could potentially serve as a bottleneck for the policy implementation.

Conclusions

The outcomes of this study were highly favorable and aligned with our initial expectations. The alternative hypothesis posited that the HRVB protocol would yield positive effects on both self-regulation and performance.

Self-regulation is the professional's ability to stimulate the parasympathetic nervous system to counteract the "fight or flight" response triggered by the sympathetic nervous system when facing a stressful stimulus, thereby promoting internal balance. This capacity can be developed through HRVB practice, which we anticipated would result in a reduction of maximum heart rate as evidence of improved self-regulation. Similarly, we aimed to decrease the performance score to reduce procedural failures and response time.

When police officers can self-regulate during acute stress, they are more likely to access their memory-based knowledge and previous practical experiences without compromising their motor skills, which are essential for implementing operating procedures.

Therefore, to reduce the number of deaths caused by the misuse of lethal force, police organizations must continue to invest in standard training to increase knowledge and skills. However, to effectively translate these gains into practice, especially in life-threatening situations, it is critical to combine standard training with the heart rate variability biofeedback protocol.

Nevertheless, from the standpoint of the organizational strategy designed to enhance police operations, the examined protocol does exhibit limitations, albeit ones amenable to control. Enhancing the HRVB protocol stands as a significant investment, given that the study's findings substantiate the role of physiological modulation in facilitating prompt and organizationally aligned responses during armed reactions. Meeting such requisites is crucial for attaining an appropriate level of force utilization by public security agents under acute stress conditions. In other words, the capacity to foster self-regulation in the face of life-threatening risks has the potential to preserve human lives.

In light of the substantial contribution made by this empirical study to the field of public security, the subsequent phase will involve an in-depth exploration to mitigate the identified limitations and enhance the tested protocol.

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