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ERGONOMIC ANALYSIS OF THE TACTICAL FORCE VEHICLE OF THE 11th MILITARY POLICE BATTALION OF SÃO PAULO

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ABSTRACT

The present study aimed to perform an ergonomic analysis in a police vehicle, to provide better working conditions to officers, most specifically at the 11th São Paulo State Military Police Tactical Force Battalion. The police must carry out several operations in their file, among them, patrolling, in which the respective have a working day of 12 hours a day maximum, provided by law, in shifts of 12x36 hours. For more than 99% of the cases, the patrol operation is carried out with 3 officers by command of the Military Police, where the officer located in the rear portion of the vehicle needs to cover the rear and side of the vehicle, forcing him to perform a torsion in the lumbar and neck. The activity is performed at a frequency of 7 times per minute, resulting in several occurrences of low back pain. Having that pointed out, it was verified the need to adapt the work environment, to provide better operational and ergonomic conditions. For the case study in question, the NIOSH, OWAS, RULA, REBA and Couto Checklist methods were used Ergolândia software. It was possible to simulate the movement of officers during the operation. These methods were selected with the purpose of facilitating the understanding of the elaborated material, resulting in ergonomic bases analysis for the proposed changes inside the vehicle. With these changes, an ergonomic improvement of 28.57% was obtained, providing better conditions of work for the police, and thus, returning to the labor issue, proving that it is possible to provide better working conditions to the officers of the 11th São Paulo State Military Police Tactical Force Battalion.

KEYWORDS: Military Police, Ergonomic Analysis, Vehicle, Operations, Patrol, Field of Vision, Working Conditions, Low Back Pain, Methods, Software, Simulate.

1. Introduction

The concept of organizations promoting health in the workplace is that organizational and personal well-being are interconnected, and there is an effective management practice to combine these two aspects. This practice emphasizes efficiency, creating an organizational climate supportive of performance, effective use of human resources, and reduction of obstacles. Ergonomics researchers conducted a study to identify organizational practices involved in creating an entity that promotes health at work along with organizational efficiency, ergonomic design, and reduction of work-related stress (SAUTER et al., 1991). This institution focuses on quality, invests in employee development, engages in strategic planning activities, and provides fair pay and awards. Many of these activities are aspects of

effective management that emphasizes quality and innovation. Numerous countries have laws specifying the maximum allowable level of health risk in a job. (According to Gomes da Silva et al., [no date]):

> Organizations have always had as their main objective the pursuit of improved productivity rates. Due to the phenomenon of globalization, productivity has become a significant differentiator in the competitiveness of companies. Industrial activity, for example, grows each year, and in this sector, a large number of workers are directly involved in production and manufacturing areas. As a result, recent studies show an increase in employee absenteeism due to work-related illnesses, prompting companies to adopt appropriate ergonomic policies for this type of work.

It is evident that ergonomic problems are present in diverse activities, sharing a common factor: employee absenteeism due to ergonomic issues, leading to a reduction in productivity and increased costs for the company (GOMES DA SILVA et al., [no date]).

These problems are observed in various contexts, such as with police officers who hold positions with high risks, facing a range of occupational hazards compared to other professionals. Statistics on workplace accidents are challenging to interpret. Rates are calculated differently from study to study, perspectives are limited, and comparing with other types of professions becomes practically impractical due to a lack of relevant information resulting from insufficient data. Studies often focus on injuries in police officers that most commonly occur in the back, hands, fingers, knees, and legs (MAYHEW and GRAYCAR, 2001). As indicated by medical statistics and empirical research data (HELIÖVAARA, 1988), back pain is the most impactful ergonomic risk and consequently requires heightened attention.

Thus, this work aims to demonstrate that ergonomics is of paramount importance to stakeholders, including the Military Police Institution, the State of São Paulo, operational officers, and society. The goal is to improve working conditions and meet the interests of the organizations.

This work aims to conduct a study proposing improvements in the working conditions of military police officers, aligning with the interests of the State Government of São Paulo, the Military Police Institution, and society. These improvements will be based on a comprehensive macro and micro ergonomic analysis of the workplace (vehicle); positioning of operational officers within the vehicle; analysis of the prescribed task and the activity actually performed, taking into account both physical (vehicle-related) and financial (government expenses on officers on leave) limitations. The focus is on optimizing resources and, consequently, increasing productivity, not only for profit-seeking purposes but primarily for the physical health of the police officers.

2. Literature Review

2.1. Working Conditions Of Military Police Officers

Military police officers, in general, undergo a structured work routine that begins with the reading of the daily order, which includes all the instructions they need to carry out their respective activities according to the work schedule. This includes pre-operation patrol training, the actual operation, and the return to the police base. They often work long shifts of up to 12 hours a day, or even 12-hour shifts with 36 hours off, posing significant risks due to the nature of the operations, in addition to all the psychological factors involved.

Furthermore, there are three factors contributing to the unhealthiness of the activity. These are:

- Risk: From the moment an individual's profession involves protecting others with confrontations and violence, it inherently takes on a connotation of a dangerous activity. In this context, according to Bernstein (1997), police officers are classified as working under a high epidemiological "risk," which is the likelihood of injuries, traumas, and deaths occurring. This can bring to the operational officer the impulse and willingness to confront such risks.
- Physical Health: The work of a police officer demands exaggerated and repetitive movements, intense training, and exposure to projectiles, leading to physical problems, muscular pain, fatigue, fractures, and consequently, absences from their routine activities. Additionally, operational officers are not adequately prepared to carry out this type of activity on such a scale due to insufficient support in terms of working conditions (DE SOUZA and MINAYO, 2004). According to Minayo et al. (2008):

  > Enlisted personnel complain about various situations related to medical care, the diseases themselves, and also highlight difficulties associated with the process of obtaining medical leave. They directly relate their health condition to the work process: lost hours of sleep, daily stress, constant risk to life, poor nutrition, and the intensity of work.

- Mental Health: As they perform their duties almost always under pressure, the police officers, for the most part, tend to suffer from psychological problems, depression, high stress, and even psychiatric disorders.

The reflection by Brant and Minayo-Gomez (2004) contributes to understanding the situation of the officers:

> It is important to recognize that suffering does not have a singular manifestation for all individuals within the same family, culture, or historical period. What is suffering for one person may not necessarily be so for another, even when subjected to the same adverse environmental conditions. Additionally, what is suffering for someone may be pleasure for another and vice versa. An event, capable of causing astonishment at one moment, can signify suffering; at another, it may be experienced as satisfaction. It is also important to note that in suffering, it is possible to find a mixture of pleasure and pain simultaneously.

Therefore, it is of paramount importance to have a holistic approach concerning the mental and physical health of police officers so that they can perform their duties with excellence, minimizing the maximum possible risk of the activity and eliminating the occurrence of errors due to lack of support.

2.2. Ergonomic Work Analysis

Iida and Buarque (2016) assert that Work Ergonomic Analysis (WEA) aims to apply ergonomic concepts in a real work context, aiming to diagnose and correct points that are classified as a threat to the worker's health. The WEA method consists of five stages: demand analysis, task analysis, activity analysis, diagnosis, and recommendations (GUÉRIN et al., 2001).

According to the Ministry of Labor, based on Regulatory Standard 17 (BRAZIL, 1978), to assess the adaptation of working conditions to the psychophysiological characteristics of workers, it is the employer's responsibility to conduct ergonomic work analysis, which should address, at a minimum, the working conditions. These include aspects related to lifting, transportation, and unloading of materials, furniture, equipment, environmental conditions of

the workplace, and the organization of work itself.

WEA can be applied to any type of work, as long as it follows the five steps presented by it, with the first three being analytical, providing the basis for the diagnosis to make recommendations.

According to Iida and Buarque (2016), demand analysis seeks to understand the root and dimension of problems in a particular situation under study. However, often this problem is presented partially, masking others of greater relevance (SANTOS AND FIALHO, 1997). According to Iida and Buarque (2016), task analysis seeks irregularities between the described work and what is actually done, while activity analysis is divided between internal and external factors. The internal factor refers to the employee's behavior in carrying out their assigned task, their training, experience, disposition, motivation, and as an external factor, there are the conditions to which this employee is exposed, unfolding into: work organization, content (standards, rules, and objectives), and technical means (machines, equipment, among others). The diagnostic formulation stage aims to identify the causes of the reported problems, relating them to the factors found in the task and activity analysis stages.

As a result of this process, ergonomic recommendations are obtained, that is, the steps to be taken to correct the ergonomically inadequate situation, and essential stages are raised to solve the problem, with people, sections, or departments responsible for such changes and implementations within a defined timeframe.

2.3. Consequences Of Lack Of Ergonomics

Regarding workers, it is necessary to consider the various environmental and organizational risks to which they are exposed, based on their integration into work processes. Therefore, worker health actions should be formally included in the agenda of the basic health care network. This expands the assistance already offered to workers, as they are viewed as subjects susceptible to specific illnesses that require specific strategies for health promotion, protection, and recovery (BRAZIL, 2002).

According to Mafra and Vidal (2006), in a production process, there are losses such as failures in health management, environmental issues, and occupational safety. In addition to asset losses, efficiency, and productivity losses, which are not always evident in management reports. In this sense, the ergonomics methodology makes failures and their respective losses evident. It should be noted that, according to Mafra and Vidal (2006), ergonomic costs are the result of the absence of ergonomics.

Thus, losses in the process, whether direct or related to ergonomic problems, are then classified as "ergonomic costs," demonstrating that the absence of ergonomics could be characterized by economic indicators of effectiveness. In other words, choosing ergonomics does not entail incurring or incorporating new expenses, expenditures, or costs; instead, it involves investing in the optimization of productive resources. It is a capital inversion whose return and risks can be reasonably estimated, like any other investment option in the company.

In this way, the term "ergonomic costs" has been coined to refer to losses in the process due to poor ergonomics or its absence. In this approach, improving the process should not be understood as spending on improvements; it is, in fact, an investment because it triggers profits and brings returns and benefits over time (MAFRA and VIDAL, 2006).

In the military police activity, individuals are exposed to a series of factors that can interfere with their health. Many police officers perform operational activities, where they must make constant movements, carry relatively heavy artifacts, leading to overloading the spine and, consequently, lower back pain. To illustrate this assertion, in the state of Bahia alone, in 2013, there was a expenditure of R$1,500,000.00 on salaries for police officers on sick leave due to

lumbago (TAVARES NETO et al., 2013).

It is worth noting that, due to the absence of publicly available data provided by the State of São Paulo, an example from the State of Bahia was used only as a way to illustrate the extent of the studied problem.

3. Methodology

3.1. Data Collection Procedure

3.1.1. Informal Conversations And Semi-Structured Interviews

Initially, informal conversations were held with soldiers, corporals, sergeants, and lieutenants who actively participate in operations to structure the issue at hand and collect initial data. The goal was to identify possible solutions while also measuring, on a macro level, what would be defined as a point to be optimized in the overall work. The collected data included:

- Working hours (12 hours per day in 12 x 36-hour shifts);
- Work routine (Training, operation instruction, operation, and return);
- Trainings (physical and psychological);
- Types of operations (for the purposes of this study, only patrolling was considered).

3.1.2 Direct Observation Of Operations And Workplace

- Five visits were made to the courtyard of the 11th Battalion of the Tactical Force of the Military Police, where it was possible to obtain a holistic view of the workplace of the police officers (vehicle). For each visit, a position of the officers in the vehicle was studied. Furthermore, by observing more closely and meticulously the operations carried out by the officers of the respective Military Police Battalion, it was possible to collect more detailed data. Among the collected data are:
- Movement of the police officers;
- Equipment used (such as holster, belt, weapons, and vest);
- Spacing and dimensions of the vehicle (Figure 1 and Figure 2).

Figure 1 - Lower lateral measurement of the rear door

SOURCE: Authors

3.1.3 Image And Video

Photos were captured using professional DSLR digital cameras with the aim of observing in more detail the positioning of the police officers at their workplace (vehicle). Additionally, obtaining videos recorded by the authors' mobile phones was essential for a better understanding of how the movements were carried out by the officers while performing their activities.

3.1.4 Questionnaire

With the aim of compiling the requests of the officers, a survey was conducted using a questionnaire, as shown in Appendix I, which contains 44 questions, intended for the Tactical Force of the Military Police, more precisely in the 11th Battalion of the city of São Paulo. Among the collected data are

- General information about the police officers;
- General information about the operations;
- General information about the 11th Battalion of the Tactical Force of the Military Police;
- Information about the reasons for the officers' absences.

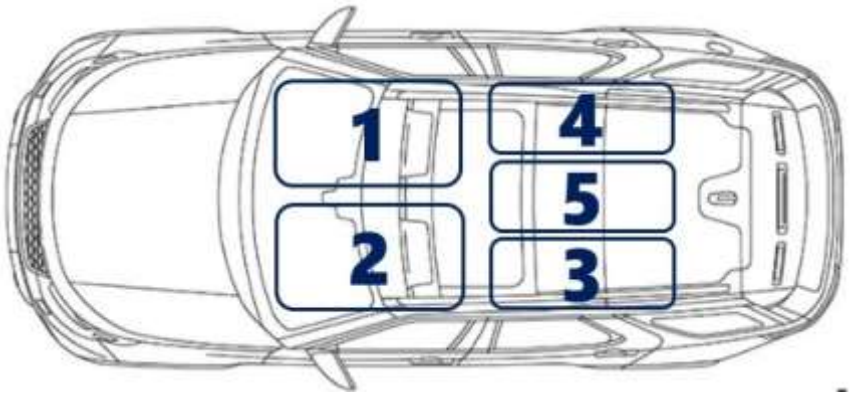
3.2. Military Operation Details

To understand the military operation, it is crucial to highlight what should be considered as prior knowledge for a complete understanding and interpretation of the data analysis.

The military police force comprises 84,290 operational officers, with 31.14% of this number serving in the Tactical Force in the state of São Paulo (ARCOVERDE, 2016), with a fleet of 420 Tactical Force vehicles for a population of 43,461,491, according to the FIQUEM SABENDO website (ARCOVERDE, 2016). This means there is approximately 1 Tactical Force officer for every 16,557 inhabitants by estimation, considering there are 105 battalions with an average of 25 Tactical Force officers each.

During an operation, the team can work with three, four, or five officers. The positions and their respective tasks are described in Figure 3:

Figure 3 - Top view of the positioning of police officers at the workstation



SOURCE:< https://blocoautocad.com/e/modelo-de-carro-simples-vista-superior/>

- Position 1: Commander
- Position 2: Driver
- Position 3: Most experienced officer
- Position 4: Less experienced officer
- Position 5: Extra officer

Positions one, two, and three are essential for the operation and are typically the most utilized. The roles filled by positions one and two are responsible for supervising the front part of the vehicle and a portion of the lateral area through the side mirror. Positions three and four are tasked with monitoring the larger portion of the vehicle's lateral area and the rear through body movements. The most experienced officer works more effectively in cases of threats to civilians, operations, and against the vehicle itself. Position four is intended to assist with lateral and front views, occupied by the less experienced officer, and their role is more linked to documentation of violations. Finally, position five is necessary in cases of CDC (Civil Disturbance Control) actions and is occupied by the less experienced officer, with a role more focused on documenting violations. It is worth noting that in over 99% of cases, the police operate with three officers as a norm.

3.3 Procedure For Data Analysis

3.3.1. Analysis Of Data Acquired From Informal Conversations And Semi-Structured Interviews

The initial primary data was collected through informal conversations and semi-structured interviews with the following members of the Military Police: Colonel Temístocles Telmo Ferreira Araújo, Captain Luis Humberto Caparroz, Lieutenant Davi Carlos Queiroz, and officers from the 11th Battalion of the Military Police (PM). These data were useful for identifying the main concerns of the police officers, understanding the type of research to be conducted, the norms the police must follow in their operations, the availability of resources, and also served as a basis for the questionnaire developed.

3.3.2. Analysis Of Data Collected Through Visits To The 11th Military Police Battalion

After 5 visits to the 11th Battalion of the Military Police, it was possible to observe police operations, their difficulties, and identify the main constraints of the officers regarding the workplace, allowing for the identification of some problems. Throughout the observed period during the visits, important facts about the daily activities performed by the officers, especially in operations carried out in the vehicle, could be abstracted in this case, the focus of the study.

3.4 Mapping Of Operations And Positioning Of Police Officers

In order to organize the sequence of operations performed and identify the most harmful to the police officers (critical point), a kind of mapping of operations was carried out using Excel, assigning weights (from 1 to 5, with 5 being the highest weight) based on the degree of complexity by the positioning of the police officers in the vehicle and the frequency of their movements. For better visualization, Table 1 is presented.

Table 1 - Mapping of operations vs. positioning of police officers

	Operation			
Position	Patrol	Lantern	Driving	Total / Position
1st Man	4	-	-	4
2nd man	1	-	5	6
3rd Man	**5**	**5**	**-**	**10**
4th man	5	5	-	10
5th man	3	-	-	3

SOURCE: Authors

3.5 Analysis Of The Applied Questionnaire

Through all the notes made in the previous items, it was possible to elaborate a complete questionnaire with different aspects, encompassing general, personal, and operational data related to the police officers. This aimed to consolidate the topics covered so far, allowing the present work to achieve its objectives of identifying and structuring the main problems.

3.6 Analysis Of Data From Bibliographies, Scientific Articles, And Government Platforms

The combination of data collected from bibliographies and scientific articles with data obtained from government platforms allowed for the analysis of the total number of police officers in the state of São Paulo versus the number of police officers on sick leave due to low back pain versus government spending on sick leave for police officers in accordance with the law, aiming to obtain a productivity indicator.

3.7 Analysis Of Data Collected Through Image And Video

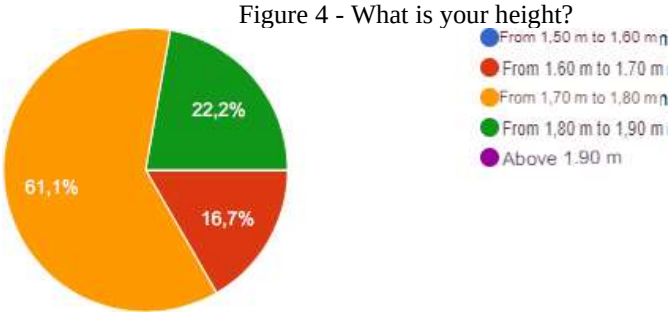
With the use of technological resources, such as the Ergolândia software, it was possible to analyze the angle and frequency of movement of the officers, angle of the field of vision, angle of neck and back torsion, restrictions faced in movement, spacing of the vehicle, internal measurements of the vehicle, and classify them according to the methods used in this work. These methods involve calculation and simulation software, providing both quantitative and qualitative results, which will be presented in the next chapter.

4. Results And Discussions

4.1 Application Of The Questionnaire

The questionnaire yielded 18 responses, representing 72% of all employees of the Tactical Force of the Military Police of the 11th Battalion in the state of São Paulo. The other 7 employees did not respond because they are not currently active, 2 are on sick leave due to low back pain, 1 is on vacation, and the others chose not to respond. The questionnaire consisted of 44 questions, and the results obtained confirmed the need for ergonomic adjustments in the workplace. All results from the questionnaire are presented in Appendix I. However, there are some responses that highlight more incisively the problems in the employees' activities and will be described below. As shown in Figure 4, there is a considerable height difference, as the variation is specified between 1.60m and 1.90m and should be considered for ergonomic analysis.

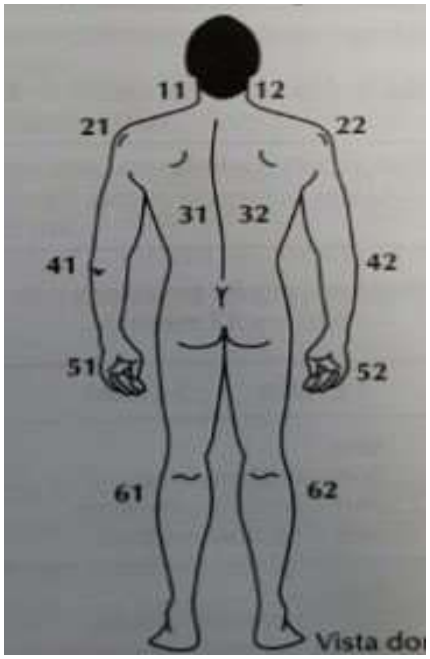
Figure 4 - What is your height?



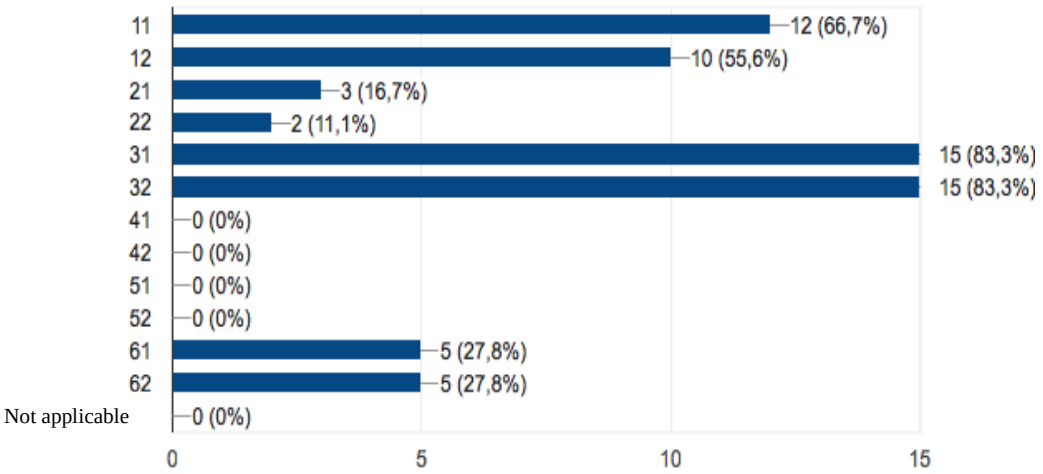
SOURCE: Authors

Figure 5 presents a pain diagram where respondents could indicate in which regions they have experienced discomfort due to the daily operations to which they are subjected. According to the responses obtained, 15 out of the 18 employees who answered the survey reported that they have experienced discomfort in regions 31 and 32, i.e., the lower back area. Two other points of high relevance are regions 11 and 12, which received 12 and 10 responses, respectively, indicating that respondents have experienced discomfort in these regions (Figure 6). These results indicate the need for a proposal to improve working conditions (which will be further developed throughout the project), as the constant rotation performed in the daily activities by the police officers in their workplace suggests a need for change.

Figure 5 - Regions of the human body



SOURCE: (IIDA and BUARQUE, 2016)



SOURCE: Authors

During the operation of the police officers, it was observed that there is a clear need to cover the entire field of vision of a car, which may require the employee to rotate up to 123.79 degrees during an operation. Figure 7 confirms the need to obtain visibility of the field of vision, where approximately 67% of respondents reported that they fully agree with the statement described.

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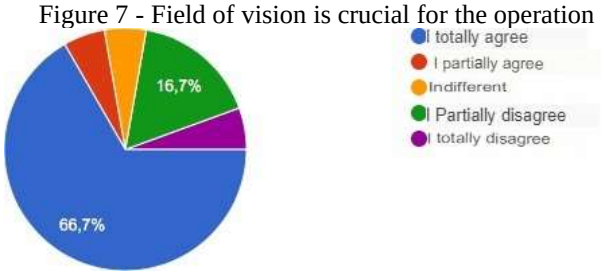
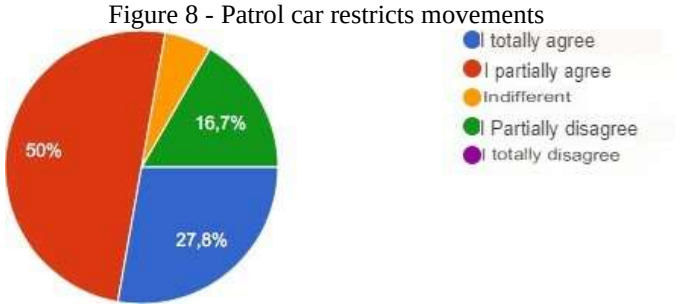
Figure 7 - Field of vision is crucial for the operation



SOURCE: Authors

Figure 8 highlights the difficulty of movement for police officers due to the fact that the vehicle is not adapted to the necessary movements to perform tasks. The results of the respondents show that 27.8% fully agree, and 50% partially agree that the vehicle hinders/limits movements.

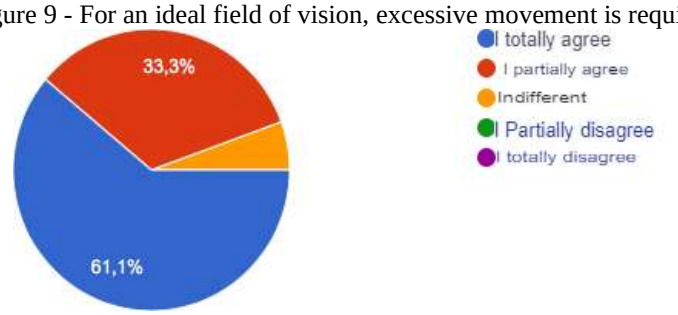
Figure 8 - Patrol car restricts movements



SOURCE: Authors

During the observation of police operations, it became clear that there is excessive movement required to perform tasks, given the need for employees to cover the entire field of vision. Figure 9 shows that 61.1% fully agree with this statement, and 33.3% partially agree, confirming this fact.

Figure 9 - For an ideal field of vision, excessive movement is required



SOURCE: Authors

4.2 Image Analysis

During the visit, the movements performed during the operations were simulated. To develop quantitative methods, the Ergolândia software was used for image analysis between the operations officer and the workstation. It was observed that, due to the fact that officers occupying positions three and four need to supervise rear areas, there is a rotation of 86.8 degrees for lateral visibility and 123.79 degrees to acquire the rear field of vision, as highlighted in Figure 10 and Figure 11, respectively.

It is worth noting that, due to physical limitations of the workstation, it was not possible to obtain images from the top view of the officer inside the vehicle. It is essential that, to measure the rotation angle of the operation in question, it be performed exclusively through the top view.

Thus, aiming for accuracy to validate the test, the image analysis was performed on the outside of the vehicle, simulating the same movement that the operations officer would make inside it. The test was conducted parallel to the vehicle, where the ladder illustrated below represents the limitation that the side door offers to the movements of the officers. Analogously to this, a reference point was used so that the simulated field of vision was faithful to that of the real operation.

Figure 10 - Rotational movement for obtaining a lateral field of vision

SOURCE: Authors

Figure 11 - Rotational movement for obtaining a rear field of vision

SOURCE: Authors

In addition to assessing rotation angles, the seat inclination is also a factor that influences the performance of police operations, as individuals have to exert significant axial force to lean forward to obtain the ideal field of vision for the operation. It was possible to measure the inclination, as shown in Figure 12, with the obtained value of 14.96 degrees:

Figure 12 - Inclination of the rear seat from the side view

SOURCE: Authors

4.3 Current Operation

Based on the Ergolândia and Ergonomics tools, it was possible to perform simulations and analyze quantitative and qualitative scenarios to obtain numerical and analytical results. The results model exposes the current operation carried out by the collaborators of the 11th Tactical Operations Battalion of the Military Police, where all calculated values consider the mass of the bulletproof vest added to the weapon, 5 kg.

4.4 NIOSH

Through the quantitative NIOSH method, the result of the Lifting Index (LI) was obtained as shown in Figure 8. The worst-case scenario for the rotation of the back and neck to achieve an angle of 123.79 degrees was calculated, considering intermittent movement 7 times per minute.

Thus, it was possible to obtain a Lifting Index result classified as poor, i.e., greater than 1 (Figure 13).

Figure 13 - NIOSH Method for load lifting

SOURCE: Authors

4.5 OWAS

Through the qualitative postural analysis method OWAS, as shown in Figure 14, the result of action category 4 was obtained: "Immediate corrections are required."

As can be observed, the method considers the posture of the back, the posture of the arms, the posture of the legs, and the effort exerted. The first is classified as inclined and twisted, the second presents both arms at shoulder level or above, the third with flexed knees, and finally, a load less than 10 kg.

Figure 14 - Posture analysis by the OWAS method

SOURCE: Authors

4.6 RULA

By the RULA method, two positions for quantitative analysis were set up in the Ergonomics software. The first position, shown in Figure 15, considers the police officer in a static state, that is, sitting without constant movement. It is worth noting that the Ergonomics software analyzes, based on the chosen method, the posture of the body's limbs and shows the fatigue they undergo according to movement or position, providing an overall result and a recommendation within a range from 1 to 7, with 7 being the worst case. In this first case, the obtained result was categorized as level 4: "Future investigation."

Figure 15 - Posture analysis by the RULA method (static position)

SOURCE: Authors

In the second case evaluated, the dynamic positioning of movement is considered, similar to the analysis by the NIOSH method, with the largest rotation angle being 123.79 degrees. The result obtained, as shown in Figure 16, was categorized as level 7: "Investigate and change immediately."

Figure 16 - Posture analysis by the RULA method (dynamic position)

SOURCE: Authors

4.7 REBA

Through the REBA method, the evaluation parameters were configured in the Ergolândia software:

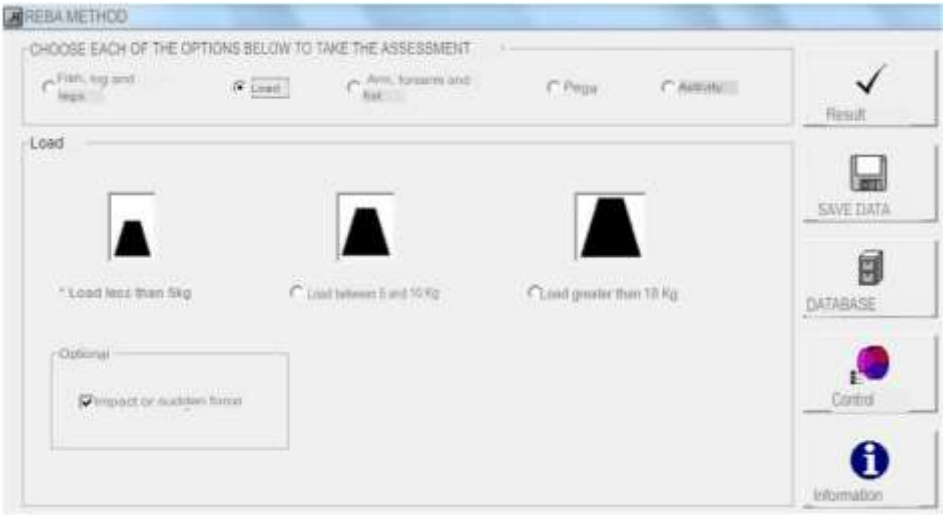
- Neck, trunk, and legs;
- Load;
- Arm, forearm, and wrist;
- Grip;
- Activity..

The classification of the parameters can be seen in Figure 17 to Figure 22.

Figure 17 - Evaluation of the limbs: neck, trunk, and legs using the REBA method

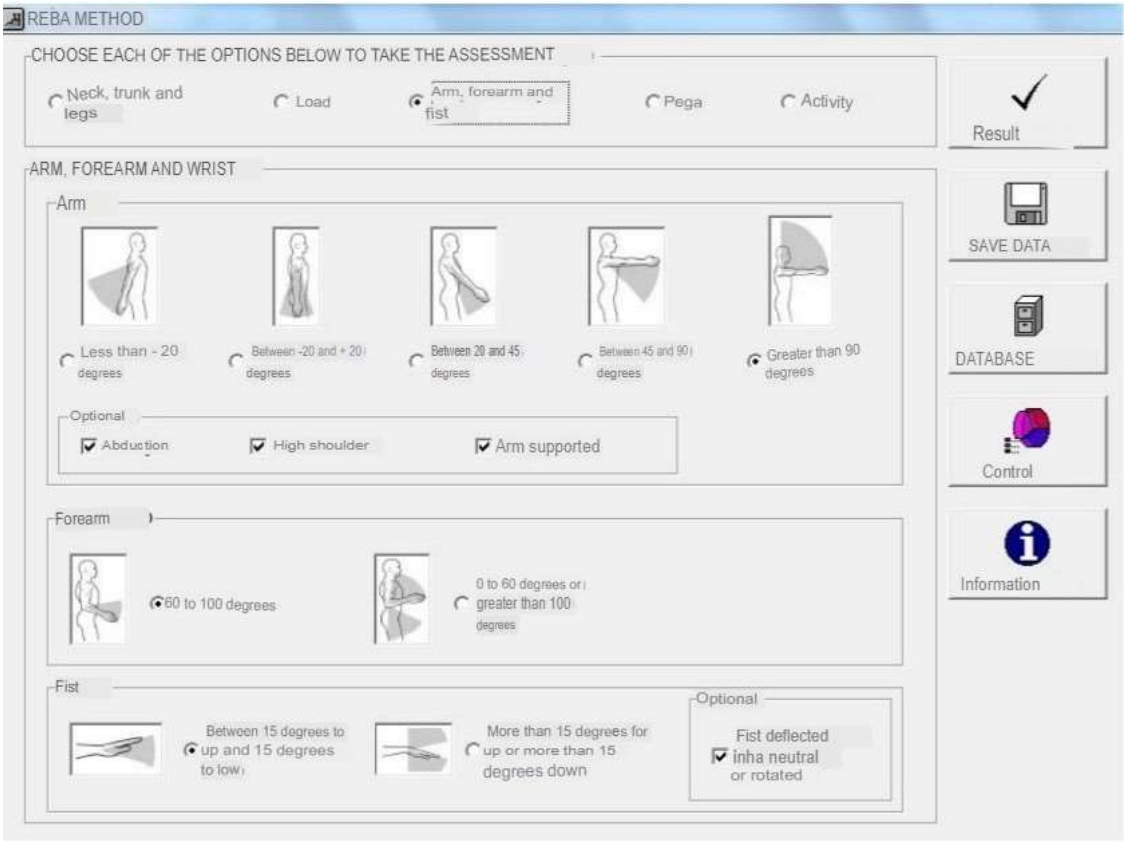
SOURCE: Authors

Figure 18 - Load assessment using the REBA method



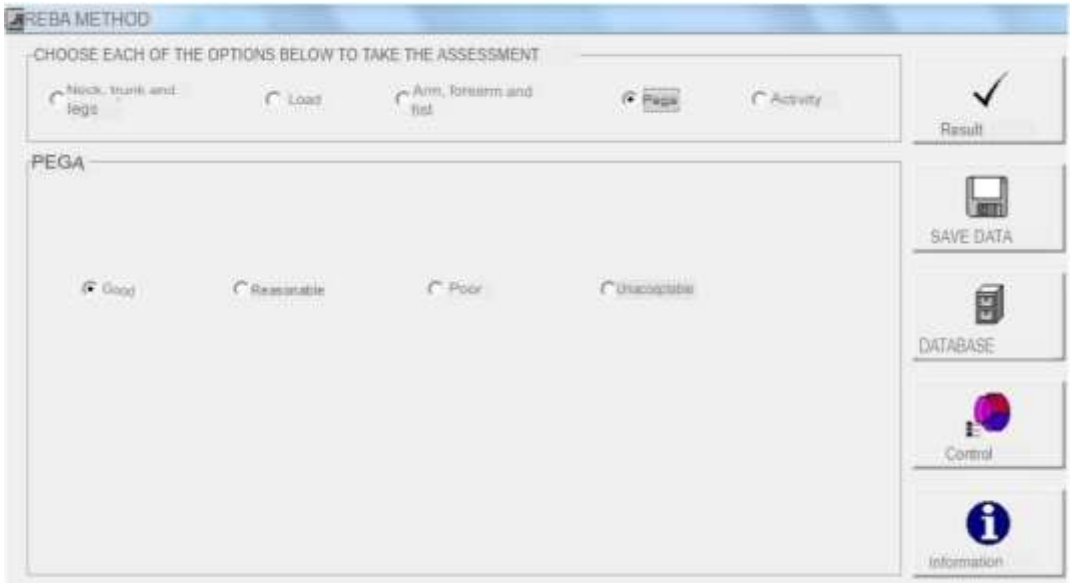
SOURCE: Authors

Figure 19 - Evaluation of the arm, forearm, and wrist using the REBA method



SOURCE: Authors

Figure 20 - Grip evaluation using the REBA method



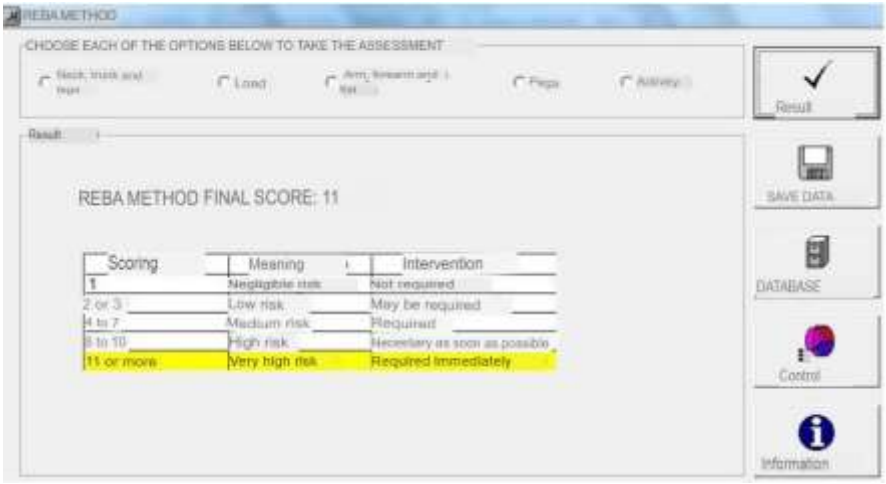
SOURCE: Authors

Figure 21 - Activity assessment using the REBA method

SOURCE: Authors

The result presented in Figure 17, after the insertion of parameters, obtained a final score of 11 or more, indicating a very high risk and the need for immediate intervention.

Figure 22 - Result of posture analysis using the REBA method

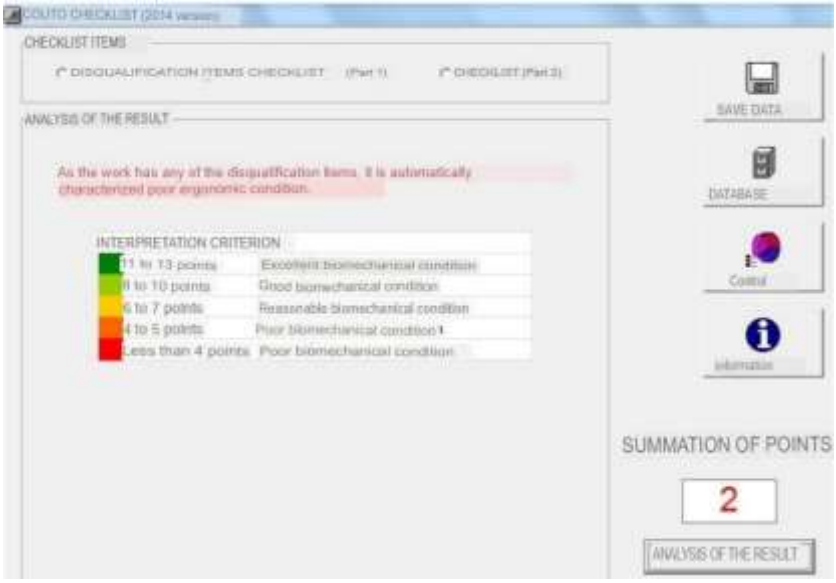


SOURCE: Authors

4.8 Couto Checklist

The Couto checklist was evaluated for measuring the risk of musculoskeletal disorders in the upper limbs related to work. The result obtained from this method was 2 points, indicating a poor biomechanical condition; see Figure 23.:

Figure 23 - Result of the Couto Checklist



SOURCE: Authors

4.9 Hypotheses For Solution

Through the analysis of the operation, questionnaire, visits, informal conversations, and semi-structured interviews, the proposed problem to be solved subjectively was identified. After the analysis of Image, NIOSH, OWAS, RULA, REBA, and the Couto Checklist, the need for an adaptation of the vehicle for the police officers' activities at the workplace was confirmed, considering that each officer works in an intensive patrol for a maximum of 12 hours a day, as stipulated by law.

Considering the criticality of the position, as the required body rotation for the activity to

cover the entire field of vision is very high, and due to the fact that more than 99% of operations involve three police officers, the focus on solving the problem specifically considered position 3 as the critical point, as described earlier. The definition of the critical analysis point also considered Table 3, through a mapping of operations and the respective positions of the police officers at the workplace.

A parameter ranging from 1 to 5 was created based on Table 1 in item 3.6.3 regarding the degree of movement in relation to the responsibility for the operation in the field of vision for each police officer. The First Man responsible for the front field of vision of the passenger and right side was classified at level 4, as he performs an activity requiring high attention and moderate torsion during patrol. The Second Man, the driver, prioritizes vehicle driving, as placed at level 5. However, he participates in front and side patrolling through the rearview mirror, thus classified as level 1. The Third and Fourth Men have the same function, classified as the most critical due to the effort required during patrol and also during nighttime activities for the operation, thus classified with the highest level. Finally, the fifth Man was classified at level 3, as he is in the central rear part and does not act with the same intensity in terms of rotation and movement intensity. The critical point can be identified in Figure 24, Figure 25, and Figure 26:

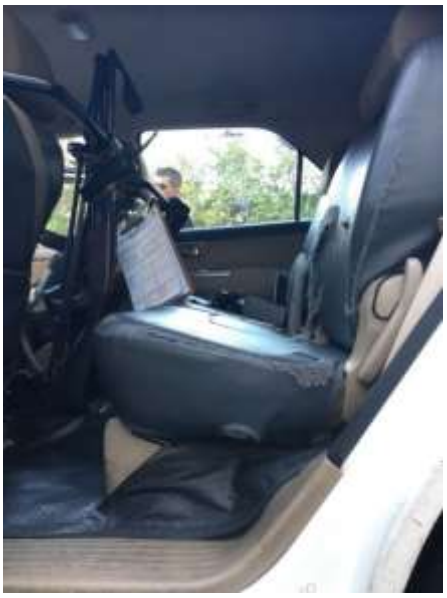
Figure 24 - Front view of the rear seat of the patrol car

SOURCE: Authors

Figure 25 - Diagonal view of the rear seat of the patrol car

SOURCE: Authors

Figure 26 - Side view of the rear seat of the patrol car



SOURCE: Authors

After the fifth visit to the 11th Military Police Battalion, the brainstorming phase began to define possible solution hypotheses for the problem. In addition to ergonomic feasibility, some other factors were taken into consideration, relating to the economic and technical viability of the hypothesis, as well as understanding the activities, workplace needs, and operational feasibility.

The first hypothesis considered was to invert the rear bench by 180 degrees, similar to the seating arrangement in a van, subway, or bus as shown in the example in Figure 27. This way, the officers in the rear bench would have visibility to the rear without excessive effort since they would be positioned facing backward.

This hypothesis was dismissed due to the fact that such a change would imply alterations to the car's structure, making the implementation time-consuming and requiring a financial investment in a new car design.

Figure 27 - Inverted seat model

SOURCE: http://negociol.com/p342322-banco-reclinvel-lugares.html

The second hypothesis analyzed involved removing one of the rear seats, allowing the two side seats to be rotated 45 degrees, positioning them in a "V" shape as highlighted with the red line in Figure 28. This arrangement would accommodate only two seats for the hypothesis. It would reduce the load on the spine since the need to cover the rear field of vision would result in a smaller body rotation, ergonomically adjusting the position of the police officer in the vehicle.

However, this hypothesis was not feasible for implementation because it would hinder the operation of CDC (Civil Disturbance Control), where 5 available police officers are required to carry out the task.

Figure 28 - Representation of the "V"-shaped seat model

FONTE: http://4.bp.blogspot.com

A third hypothesis evaluated was the implementation of a rotatable seat, as shown in Figure 29, where the seat would have flexibility to follow the movement of the police officer, resulting in a much smaller rotation of the neck and back.

This hypothesis would represent the best possible scenario; however, economic, technological, operational feasibility, and the time required for development make this model unfeasible.

Figure 29 - Representation of a swiveling seat

FONTE: http://4.bp.blogspot.com

Finally, it was possible to conclude the hypothesis used in this work. Considering the need for short-term implementation, economic and structural feasibility of the car, police operational viability, and ease of implementation, a simpler solution model was developed to meet the requirements, i.e., without modifying the current operation.

The hypothesis involved remodeling the rear seat and the door, achieving greater spacing between the seat and door, providing more rotational mobility for the police officer within their workplace. In addition to these changes, it was necessary to propose a modification to the seatbelt structure to adjust for height, as the studied sample has a height variation of 30 cm.

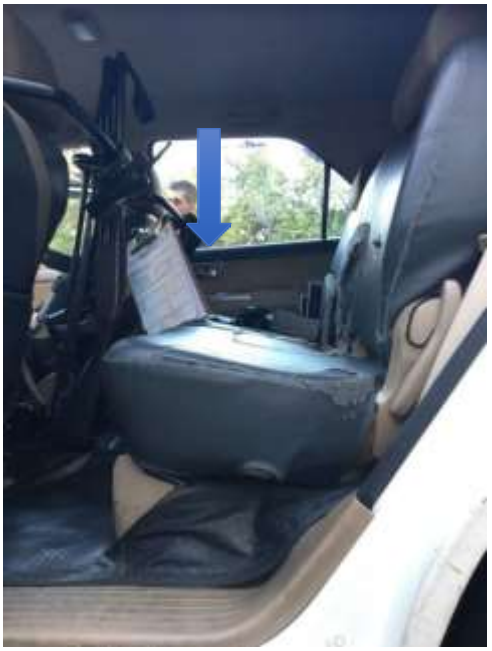
Lastly, a suggestion was made to change the angle of inclination of the rear seat, aiming to favor activities and operations through a kind of "padding." The proposed changes can be found in Figure 30, Figure 31, and Figure 32, indicated by the blue arrows.

Figure 30 - Proposed front view

SOURCE: Authors

Figure 31 - Proposed diagonal view

Figure 32 - Proposed side view



SOURCE: Authors

4.10 Improvements Achieved From The Proposed Model

Through the simulation and analysis tools, Ergonomics and Ergolândia respectively, quantitative improvements were identified in the proposed model. However, there was not a significant result in relation to qualitative methods to the extent of warranting a change in the operational status, meaning it is not classified as "immediate actions must be taken."

4.11 Image Analysis

From the proposed change, where it was feasible to increase the spacing between the seat and the side of the door by 15 cm, with 6.15 cm extracted from the seat cushion and 8.75 cm removed from the door's material, greater freedom for rotational movement of the police officers in the workplace was achieved.

The result obtained for the lateral visibility angle was a decrease from 86.8 degrees to 40.65 degrees, and the rear visibility angle decreased from 123.79 degrees to 92.06 degrees, as shown in Figure 33 and Figure 34. This implies less effort to achieve the same field of vision.

Figure 33 - Proposed rotation for lateral field of vision

SOURCE: Authors

Figure 34 - Proposed rotation for rear field of vision

SOURCE: Authors

4.12 Improvement Based On The Niosh Method

From the established proposal, considering the increased rotation angle, the NIOSH method yielded an LMI (Lifting Index) result less than or equal to 1, which is classified as good, as shown in Figure 35.

Figure 35 - Improvement achieved for load lifting

SOURCE: Authors

To obtain the improvement in quantitative factors, the equation (3) was used:

$$\text{Percentage Improvement} = 1 - (ILi ILf) \quad (3),$$

Where:

- ILf is the final lifting index after the proposal,
- ILi is the initial lifting index before the proposal.

The result obtained was an improvement of 14.47%.

4.13 Improvement Based On The Rula Method

Based on the proposed changes to the seat, it was necessary to reduce the tilt angle to alleviate leg strain and fatigue among the police officers, aiming for greater efficiency in operational visibility. As shown in Figure 36, there was a reduction in the angle from 14.96 degrees to 8.11 degrees.

Figure 36 - Improvement achieved in relation to seat inclination

SOURCE: Authors

Associated with the seat modifications, taking into account the increased rotation angle in the operation, it was possible to simulate the movement of the officers through the 3 applied changes using the Ergonomics software.

The simulated result is confirmed in Figure 37, where a final rating of 5 was achieved, meaning "Investigate and change soon."

Figure 37 - Improvement achieved in posture using the RULA method

SOURCE: Authors

To validate the improvement in quantitative factors, the equation (4) was utilized:

$$\text{Percentage Improvement} = 1 - (RiRf) \quad (4)$$

Where:

- Rf is the final value obtained by RULA after the proposal,
- Ri is the initial value obtained by RULA before the proposal.

The result obtained was an improvement of 28.57%.

4.14 Absences

As mentioned, lower back pain is one of the issues that causes a significant number of police officers to be absent from their routine activities. On average, in the analyzed battalion, 2 out of 25 officers are sidelined each year, leading to various consequences for the parties involved. These include:

- The officer themselves, as they develop a health problem resulting from their intense physical efforts;
- The police force, due to having fewer resources in its operations, hindering the ability to effectively protect society;

To the government, which, according to Law No. 10,261, of October 1968, is obligated to compensate the public servant for the period they are on leave due to activities performed at work. Note: Details of the public servant law and the work schedule of military police officers can be found in Appendices A and B, respectively.

It is evident that all parties involved stand to lose in this scenario. This situation worsens when extrapolating this number to the 105 battalions, each averaging 25 police officers dedicated to the Tactical Force, who are susceptible to operations leading to lower back pain.

Therefore, it was possible to estimate the following situation:

- 2 out of 25 officers represent an 8% absenteeism rate;
- 105 battalions multiplied by 25 officers results in 2,625 police officers dedicated to Tactical Force operations.

Thus, considering the percentage of absenteeism for all battalions in a conservative analysis, an annual absenteeism of 210 officers is estimated in the state of São Paulo, preventing them from performing their duties and triggering government expenditures.

It can be stated that the present study aimed to reduce this number of absences through simulations of police movements, resulting in an improvement of 28.57%. This represents the increased longevity of police officers before they begin to experience lower back problems.

5. Final Considerations

The study identified coherence among the factors analyzed, as internally within police groups, these factors are interconnected. Moreover, some risk factors directly counteract the initially mentioned factors, reinforcing their classification in this way. In this sense, this study contributes indicators that can numerically slow down the number of police absences due to lower back pain, which, in the study location, was confirmed to be excessively high but reduced ergonomically by 28.57%.

It's important to emphasize that these factors, as they relate to working conditions, require a cultural shift within the institution to value its workforce, providing them with the means for dignified and decent work that meets operational needs without being detrimental to those carrying out the tasks.

Furthermore, the study underscores the importance of job satisfaction, a topic extensively discussed in ergonomics, closely tied to the health domain, as evident in the concluding remarks of this study. The aim was to improve working conditions for the police officers of the 11th Battalion of the Military Police in the state of São Paulo.

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