Ergonomic Evaluation of the Use of force in the training of the Local Police of Cádiz (Spain) by REBA and Marras

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Article

Ergonomic Evaluation of the Use of Force in the Training of the Local Police of Cádiz (Spain) by REBA and Marras

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Abstract: (1) Background: This text emphasizes concerns regarding the safety of Spanish police officers attributed to inadequate training, employing biomechanics for the analysis and mitigation of risks during Use of Force training. The elevated global prevalence of musculoskeletal disorders underscores the imperative for effective occupational health measures. The study concentrates on evaluating injury risks in novice police officers during Use of Force training. (2) Research method: The movements of police officers were captured using a Rokoko Smartsuit Pro equipped with 19 sensors. The Biomechanics of Bodies software processed the data, providing REBA and Marras risk scores. Statistical tests were conducted, and Operational Tactical Procedures (OTP) were integrated into police training. A diverse group of officers participated, categorized by training level and equipped with the Rokoko Smartsuit. (3) Results: The study evaluates police force training using REBA and Marras methods. REBA scores indicate a moderate to high injury risk, suggesting effective technique design. ANOVA reveals no significant differences between training levels. Marras analysis, characterized by non-normal distribution, unveils varied risk perceptions among groups via the Kruskal-Wallis test. (4) Conclusions: The analysis of both the REBA and Marras methods implies the effectiveness of the OTP technique in reducing injury risks across different training levels. The ANOVA test indicates no significant differences in REBA Maximum Scores between the groups. However, the Kruskal-Wallis test for Marras Probability of high-risk values suggests distinctions in medians between training levels. The combined analysis visually illustrates variations in membership regions between expert, intermediate, and novice groups.

Keywords: use of force; IMUS; body injuries; police training; ergonomic; Operational Tactical Procedures

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1. Introduction

Due to recent events in Spain, where inadequately trained police officers face approximately 35 attacks per day [1], concerns have arisen in various media outlets regarding the level of self-defense training provided to law enforcement. The training for both public and private security forces is deemed inadequate or deficient. The circumstances for security forces in Spain can be likened to those of a surgeon who has received minimal training of just 70 hours and is expected to operate on patients without additional practice.

A study by Strömmer et al. [2] provides evidence that over time, law enforcement forces in the United States are causing more frequent and serious injuries to civilians. Taking a macro approach to programs, research studies conducted by Staller et al. [3] suggest pitfalls in the design of training objectives and the actual program, leading to a lack of alignment between training outcomes and the expected performance of novice police officers in the field.

Concerning European law enforcement agencies, they operate in various contexts, and their access to resources for management or training delivery is variable. Despite differences in contexts and resources, these agencies face common training challenges, such as time-consuming organizational and administrative processes required to implement changes in current training practices [4,5].

Numerous debates surround the professionalization and reform of the police, a discourse that has intensified since the death of George Floyd [6]. This heightened discussion underscores the need for a deeper understanding of the scientific methods employed in police education and training [7].

Recent research substantiates the reservations expressed in this study regarding the efficacy of police training and advocates for a more realistic approach to real-world violence [8].

Police officers on patrol encounter diverse and challenging contexts from mental, social, and physical perspectives, which can impact their overall well-being [8–10]. Recognizing these challenges, Vera-Jiménez [11] initiated a local-scale study in Cádiz, a town in southern Spain with a population slightly exceeding 100,000 inhabitants. The study aimed to provide specific training based on Operational Tactical Procedures (OTP) [12,13] to a group of municipal police officers.

The outcomes of the study indicate that the implementation of OTP procedures led to a substantial reduction in sick leave among officers during the training period and for a certain duration following the completion of the training, in comparison to periods when no OTP education was provided. This positive impact stands in contrast to conventional police training methods, currently endorsed and rooted in military instruction, martial arts, and other forms of fight and combat sports (MA/F/CS). OTP procedures were specifically developed as an alternative to classical police training [14], driven by two primary considerations: a) the potential harm inflicted on citizens subjected to Physical Intervention Techniques (PITs) [11,15], and b) the heightened risk of injury to police officers executing such PITs [13,16].

The findings underscore the effectiveness of OTP procedures in minimizing sick leaves among police officers, emphasizing a departure from traditional training approaches to enhance both citizen safety and officer well-being.

In Vera-Jiménez's study [11], an anatomical map was already devised to delineate areas on the human body of citizens for which Physical Intervention Techniques (PITs) were either recommended or prohibited. This mapping resulted from an examination of a series of judicial sentences issued by the Supreme Court, which had consequences for police officers employing force through conventional PITs [15].

Wearable sensor systems utilizing inertial measurement units (IMUs) provide kinematic information [17], proving especially valuable in ergonomic evaluations designed to capture data associated with high-risk postures and flexion frequency. These IMU systems are presently under exploration and adoption in the industry to complement or expedite ergonomic assessments [18]. While industry reports underscore the utility of IMU systems in identifying and mitigating risks of musculoskeletal injuries, manufacturers of these devices currently assert quantitative claims about

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the effectiveness and capabilities of their IMU systems in injury reduction. However, a dearth of formal, independent, or peer-reviewed studies exists to evaluate these IMU systems or the scientific foundation underpinning their risk assessment algorithms.

The processed data, acquired using the "Biomechanics of Bodies" (BoB) [19] analysis software, were subjected to a comparison with values corresponding to the newly defined Tactical Operating Procedures. This comparison relied on the REBA [20] and Marras [21] methods. BoB encompasses an extensive array of biomechanical functionalities, incorporating modeling capabilities to handle parameters such as position, velocity, acceleration (both linear extensions and angular muscle rotations), muscle tension, compressive force, and energy or power data. Additionally, BoB is equipped to generate three-dimensional graphic representations and provides various modes for data visualization.

To ascertain potential injuries that police officers may face, a suit equipped with sensors for capturing motion and other variables (Rokoko Smartsuit Pro) served as a fundamental instrument for this study. This equipment yielded a dataset that could be analyzed using Biomechanics of Bodies (BoB) software applications [19], which efficiently manages results, enabling the assessment of risks through the REBA and Marras Probability of High Risk methods.

The first method is a widely employed ergonomic tool designed to analyze and assess the ergonomic aspects of work tasks with the aim of identifying and preventing ergonomic risks in the workplace. REBA is particularly utilized in industries characterized by repetitive or physically demanding tasks, such as manufacturing, construction, or healthcare. This methodology involves a healthcare professional or ergonomist observing a worker during a specific task. The assessment takes into account factors such as body posture, required force, repetition, task duration, and exposure to vibrations. Individual scores are assigned to each of these factors, contributing to an overall ergonomic risk score. This cumulative score serves as a guide for implementing targeted improvements, which may include adjustments to operating procedures or the adoption of safer equipment. The primary objective of REBA is to mitigate ergonomic hazards, promoting a safer and healthier work environment to prevent injuries and safeguard the well-being of workers [20].

The prevalence of musculoskeletal diseases is substantial, affecting approximately 1.71 billion people globally, as estimated by the World Health Organization (WHO) [22]. These conditions constitute a significant global cause of disability, with low back pain emerging as the predominant factor in 160 countries [22]. Moreover, the annual global burden of work-related high blood pressure is estimated to be approximately 22 million disability-adjusted life years [23].

When considering the costs associated with occupational accidents and illnesses, musculoskeletal disorders (MSDs) constitute approximately 40% of the total [24]. The economic and social impact of these disruptions is reflected in estimates that place the costs at 3.9% of the global gross domestic product and 3.3% of the gross domestic product in the European Union [25].

Clearly, work-related illnesses and disorders impose an economic burden on both companies and societies at large, simultaneously affecting the individual well-being of people. This analysis differentiates between high and low risks of occupationally-related low back disorders, employing a classification system rooted in a multiple logistic regression model. This model comprises a combination of five trunk motions and workplace factors to determine the likelihood of such disorders [21,26,27].

This study specifically addresses the application of the aforementioned methods to analyze the outcomes of training novice police officers in the application of Use of Force (UOF) based on OTP basic technique 1. Our research is focused on assessing the risk of injuries associated with UOF, emphasizing the implications of the training outcomes.

The training received in the use of police force, specifically in basic technique 1 of Operational Tactical Procedures (OTP) (Figure 4), used in arrest procedures to control a standing person, was evaluated using police ergonomics parameters (PEP), as described in a previous work by Vera et al [12]. These parameters, in conjunction with Marras, were applied to a cohort of four (4) novice police officers, seven (7) with average experience, and one (1) expert. These individuals volunteered from the School of Public Safety of the City of Cádiz. The training on Tactical Operational Procedures from

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the Prosecutor's Office lasted 30 hours for new police officers, 80 hours for those with average experience, and 200 hours for the expert [12].

2. Materials and Methods

2.1. Rokoko Smartsuit

Utilizing a Rokoko Smartsuit Pro equipped with a set of 19 wireless sensors, including triaxial accelerometers, Inertial Measurement Units (IMUs), gyroscopes, and geomagnetic sensors, data capture involves various aspects such as position, velocity, acceleration, and magnetic fields of the human body. The collected data are then visually represented on a screen through an avatar, illustrating diverse postures and movements of the human body (Figure 1).

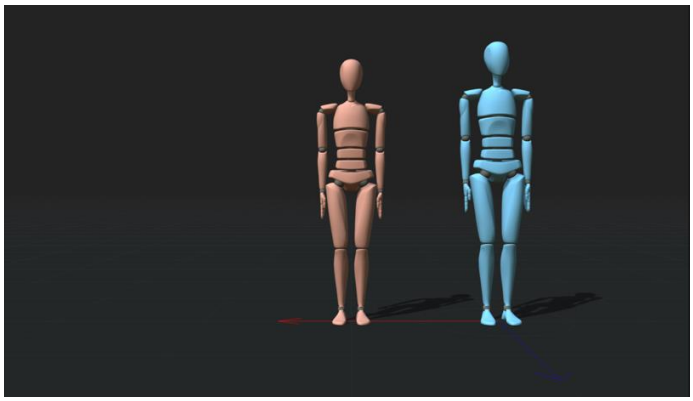

Figure 1. Smarsuit Pro equipped with a set of 19 wireless sensors, worn by police officers.

This suit facilitated the measurement of established biomechanical parameters. All police officers participating in the study performed each physical intervention technique while outfitted in the sensor-equipped suit.

2.2. Biomechanics of Bodies (BoB)

The acquired data underwent processing using the "Biomechanics of Bodies" (BoB) analysis software [19]. This software facilitated a comparison between the measured values and those aligned with the new Tactical Operating Procedures. The BoB software encompasses diverse functionalities, incorporating biomechanical modeling to handle data related to position, velocity, acceleration (both linear extensions and angular muscle rotations), muscle tension, compressive force, and energy or power. Moreover, it possesses the capability to generate three-dimensional graphic representations and provides various modes for data visualization (refer to Figure 2).

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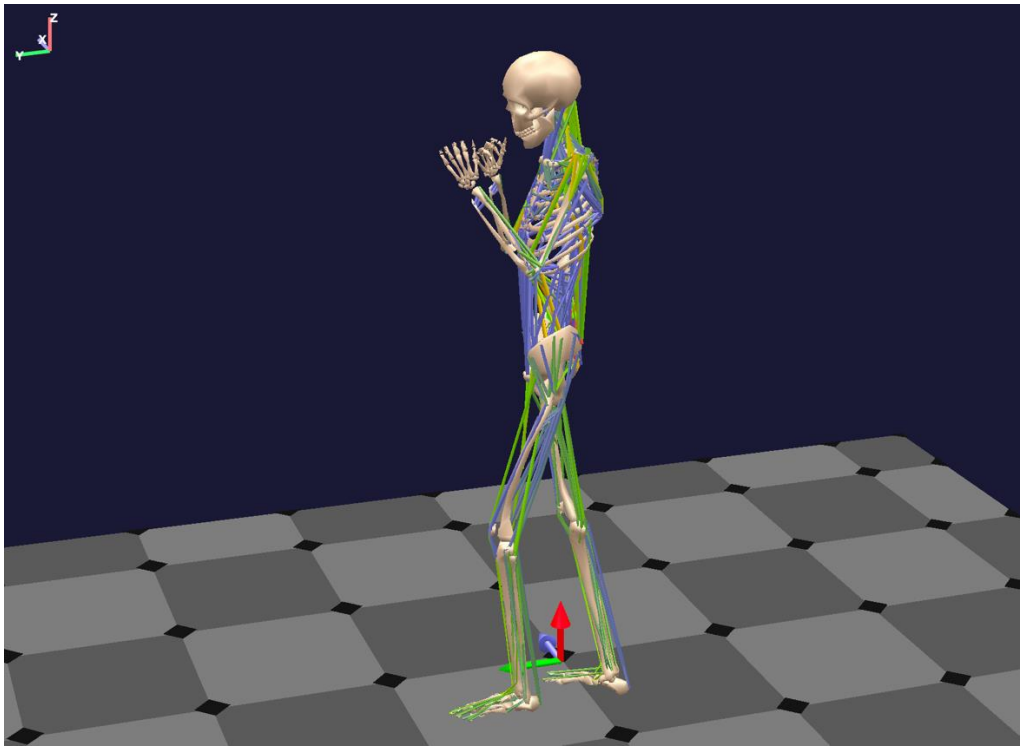

Figure 2. 3D Musculoskeletal model of the Human body by BoB software application.

"After processing the position and velocity data using the BoB software package, the REBA score (Figure 3) and Marras values (Figure 4) can be presented succinctly and directly. These results provide the risk assessment data utilized in the present study."

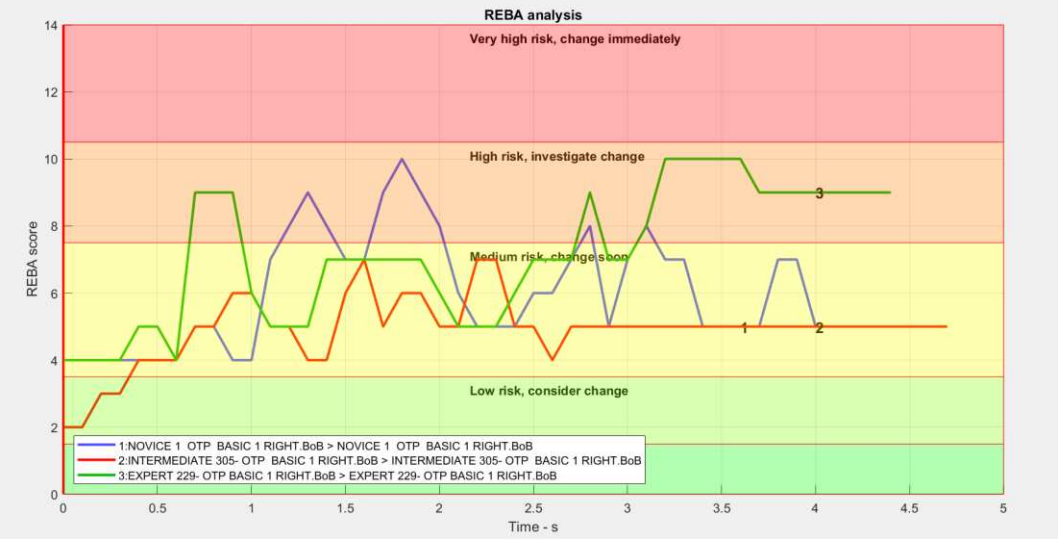

Figure 3. Plot of REBA analysis for three examples of Polices of the training level: Expert (green), Intermediate (red) and Novice (blue).

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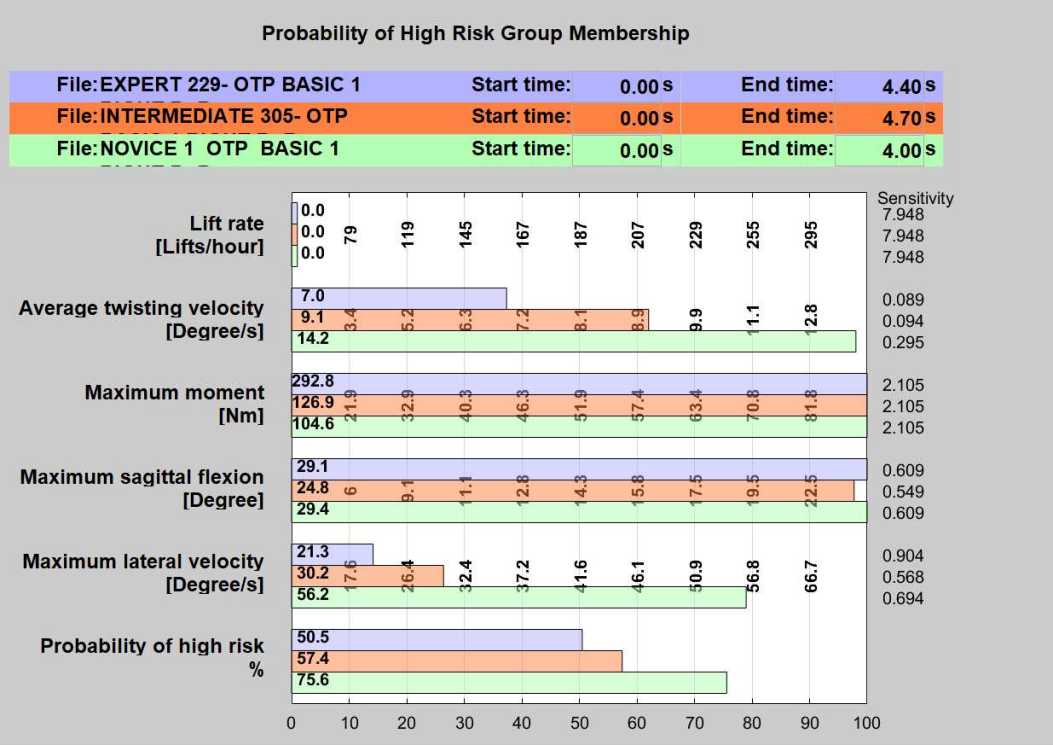

Figure 4. Grouped Bar Chart of Marras' Probability of High Risk for three examples of Polices of the training level: Expert (blue), Intermediate (orange) and Novice (green).

2.3. Statistics

Some statistical tests were required to compare the obtained results. All statistical tests and outcomes were conducted using the IBM SPSS Statistics Ver. 29.0.0.0 (241) package. Based on the type of result generated by BoB, two variables were defined: "REBA Maximum Score" and "Marras Probability of High Risk."

2.4. Operational Tactical Procedures (OTP)

The police in this study employ physical intervention techniques rooted in Operational Tactical Procedures (OTP), encompassing a range of Physical Control Methods (PCM). These methods strategically utilize upper and lower limb locks, deflections, and grips with the primary goal of averting impacts on sensitive or critical areas of the individual being apprehended. The overarching objective is to minimize the risk of inflicting serious injuries during law enforcement actions. Notably, the techniques outlined within OTP procedures emphasize the application of controlled levels of force. For instance, exerting pressure on the triceps tendon can induce significant discomfort, leading to the complete immobilization of the opponent, facilitating the officer's ability to gain control of the situation. The underlying purpose of these techniques is dual-fold: to safeguard both the individual being apprehended and the law enforcement officer from sustaining severe injuries [12]. The OTP techniques were performed at appropriate sports facilities.

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Figure 4. Basic technique 1 of the Operational Tactical Procedures (OTP). Details of this procedure can be found in [12].

2.5. The subjects who performed the corresponding tests were:

A cohort of 11 police officers was recruited as volunteers from the School of Public Safety in the City of Cádiz. All participants were equipped with the Rokoko Smartsuit. The participants were divided into three training groups based on the course duration. The training duration for Tactical Operational Procedures, provided by the Prosecutor's Office, was 30 hours for new police officers (categorized as Novice), 80 hours for those with moderate experience (categorized as Intermediate), and 200 hours for the expert level (categorized as Expert).

"All police officers are Caucasian, and their physical details are presented in Table 1. To safeguard personal data, each police officer was assigned a label, and their informed consent was obtained, in accordance with the standards set by the Ethics Committee to which this study was submitted."

Table 1. Most relevant physical aspects of police officers.

Police Officer Label	Level training	Sex	Height/m	Weight/kg
229	Expert	Male	1.83	98
282	Intermediate	Male	1.71	81
305	Intermediate	Male	1.76	76
314	Intermediate	Female	1.70	74
317	Intermediate	Male	1.75	84
334	Intermediate	Male	1.80	75
325	Intermediate	Male	1.71	81
401	Novice	Female	1.73	61
402	Novice	Male	1.90	90
403	Novice	Female	1.71	65
404	Novice	Male	1.88	105

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3. Results and discussion

The evaluation of training in the application of police force, specifically focusing on Basic Technique 1 within the Operational Tactical Procedures (OTP), utilized the REBA [20] and the Marras method [21].

3.1. REBA (Rapid Entire Body Assessment)

The assessment study of the OTP Basic 1 technique using injury risk assessment methods commences with the REBA [20] method. This involves employing the variable "REBA Maximum Score," which represents the highest score achieved by each police officer during the execution process of the OTP technique. For instance, in Figure 3, displaying the scores of police officers 229, 305, and 401, the corresponding "REBA Maximum Score" values are 10, 7, and 10, respectively. Table 2 illustrates the means of REBA Maximum Score values for the three groups of police training levels. The standard deviation for each group is also provided. The last row presents the same values for the total group (the amalgamation of the three groups), equivalent to the corresponding intergroup values.

Table 2. REBA maximum score values for three training levels and the entire group.

Group	Police Officer Label	REBA Maximum Score	Group Means	Standard deviation
1	229	10	10	--
2	282	9	9.5	1,38
2	305	7		
2	314	11		
2	317	10		
2	334	10		
2	325	10		
3	401	10	9.5	1,29
3	402	9		
3	403	8		
3	404	11		
Total			9.5	1,21

In general, it is determined that during the execution of the OTP technique, across all training levels, the REBA Maximum Scores fall within the Medium risk to High risk range but remain well below the highest risk score indicated by the REBA method (located at the uppermost region of the Very High risk area in Figure 3). This observation suggests the independence of training levels and attributes it to the effectiveness of the OTP technique, demonstrating its well-designed nature as a physical intervention method to mitigate injury risks.

Figure 5 illustrates the averages and variances of each group—Expert (blue), Intermediate (orange), and Novice (gray). Additionally, a green band depicts the intergroup variance, which is observed to be encompassed within the variances of the individual groups. This observation implies that the three training level groups exhibit no significant differences. To confirm the statistical equality of the training level averages, conducting a one-factor Analysis of Variance (ANOVA) test could be beneficial. ANOVA, a versatile statistical technique applied in diverse fields (Marketing Research, Social Sciences, Medical Research, Environmental Sciences, etc.), serves to compare means among three or more groups and ascertain if significant differences exist between them. In this study, it will be employed to scrutinize the impact of varying experience levels in the OTP technique,

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coupled with a certain degree of occupational risk assessment (REBA method), making it a single-factor analysis. This statistical test assesses whether the variance within the groups surpasses the variance between the groups, ensuring that any observed differences in means are not systematic but rather random.

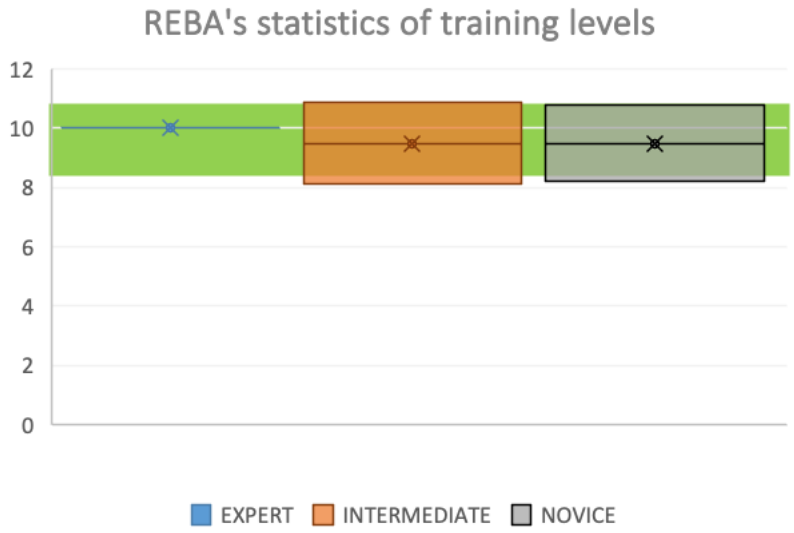

Figure 5. Box plot with the averages and Standard deviation of REBA's maximum risk value for the training levels: expert (left), intermediate (center) and novice (right). The green band represents the intergroup Standard deviation.

Nevertheless, before conducting the study, a mean analysis is performed, necessitating an examination to ascertain whether the distribution of the preceding variables follows a normal distribution—a procedure commonly referred to as a Normality test. Various tests of this nature exist, but the choice often depends on the number of variables. The Shapiro-Wilk test is frequently recommended when $n < 30$, whereas the Kolmogorov-Smirnov test is preferred for larger sample sizes ($n > 30$). Given the scale of this study ($n=11$), the Shapiro-Wilk test results are employed, although it is worth noting that the SPSS program concurrently calculates both statistical outcomes.

Both tests involve the evaluation of a research hypothesis, specifically the null hypothesis, H_0: "The population is normally distributed." The statistical metric employed in these tests is the "Significance Level Alpha." If this value exceeds 0.05 (5%), H_0 is accepted, leading to the conclusion that the set of variables conforms to a normal distribution.

3.1.1. Normality Analysis.

Applying the Shapiro-Wilk analysis to the data in Table 2, a Significance Level Alpha value of 0.110 was obtained, which is higher than the p-value of 0.05. Therefore, we conclude that the distribution is normal. Consequently, a study of the means and variances of each group can be conducted using the ANOVA test.

3.1.2. ANOVA

With the exception of the first group, Levene's homogeneity of variances test yielded a Significance level Alpha of 1.00. Conversely, the ANOVA result exhibited a Significance level Alpha of 0.940 (with an F statistic value of 0.063). In both instances, the values exceeded the threshold of p-value = 0.05, indicating that the variances and means of the three groups (Expert, Intermediate, and Novice) are significantly indistinguishable.

ANOVA is a test conducted by contrasting a null hypothesis, Null Hypothesis H_0: "The mean value of all groups is the same," against the alternative Hypothesis H_1: "There are differences in the mean values of the groups." The statistic used in this test is the "Significance level Alpha," contrasted

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with the Fisher-Snedecor F statistic, with k-1 and n-k degrees of freedom. In this study, k=3 represents the number of samples, and n=11 denotes the total number of participating police officers.

Similarly, it is appropriate to perform a variance test. In this case, SPSS also calculates the Levene statistic, allowing the testing of the hypothesis of equality of population variances (H_0). If the result shows "Significance > 0.05," we accept the hypothesis of equality of variances.

3.2. Marras method (Probability of High Risk Group Membership)

Secondly, the Marras risk assessment method described above is employed. Table 3 illustrates the probability of high-risk values. The variable "Marras Probability of High Risk" is directly obtained as a result of the BoB software. In both cases, the variables were comprised of n=11 data points, which were categorized into k=3 groups: Expert (n1=1), Intermediate (n2=6), and Novice (n3=4).

Table 3. Marras probability of high risk values for three training levels and the entire group.

Grupo	High risk %	Group Means	Standard deviation
1	50.5	50.5	--
2	57.44	72.62	7.94
2	79.51		
2	71.1		
2	76.43		
2	76.7		
2	74.55		
3	75.61	65.15	12.94
3	73.23		
3	47.06		
3	64.68		
TOTAL		67.89	11.33

Figure Figure 6 depicts a box plot for the Marras method [21]. In this instance, it is evident that the level of expertise in training is notably lower for the Probability of High Risk value, as anticipated. Conversely, the average value of the group comprising police officers with an Intermediate level of training is marginally higher than that of the novice group. The most plausible explanation is that the Intermediate training group consists of individuals who have not undergone training practices for an extended period.

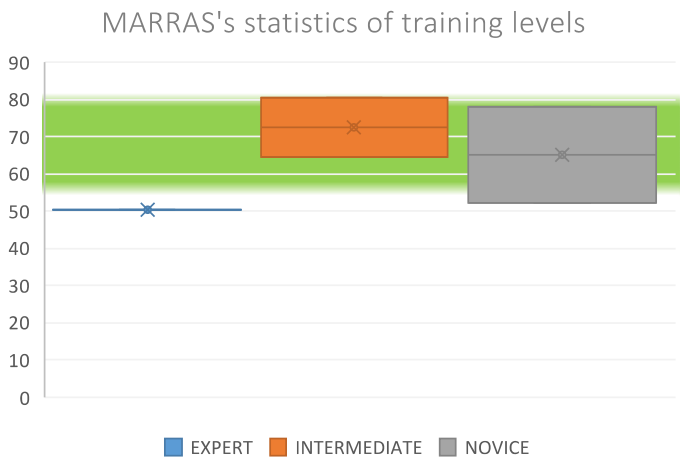

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Figure 6. Box plot with the averages and variances of Marras Probability of high risk values for the training levels: expert (left), intermediate (center) and novice (right). The green band represents the intergroup variance.

3.2.1. Normality Analysis

A study similar to the one previously conducted using the REBA method, but applied to the data in Table 3, yields different results. Similar to the approach taken with the REBA method, a preliminary step before analyzing the variance of the means of the Marras values involves examining the normality distribution of these data.

Upon applying the Shapiro-Wilk analysis to the data in Table 3, a significance level Alpha value of 0.197 was obtained, which is lower than the p-value of 0.05. Therefore, it is concluded that the distribution is NOT normal. Subsequently, an examination of the means of each group can be conducted using the Kruskal-Wallis contrast test.

3.2.2. Kruskal-Wallis contrast test

The significance result was 0.197, which, being greater than the p-value of 0.05, indicates that the null hypothesis is upheld. In other words, the medians of the "Probability of High Risk" are not the same across the categories of training levels.

This observation is illustrated in Figure 6, though it is more clearly depicted in Figure 7, where the two criteria are integrated. The x-axis represents the REBA values, while the y-axis represents the Marras probabilities. This figure illustrates the statistical membership regions of the Intermediate and Novice groups, along with the point corresponding to the police officer labeled as Expert. It is evident that the Expert's point falls clearly outside the membership regions of the other two groups.

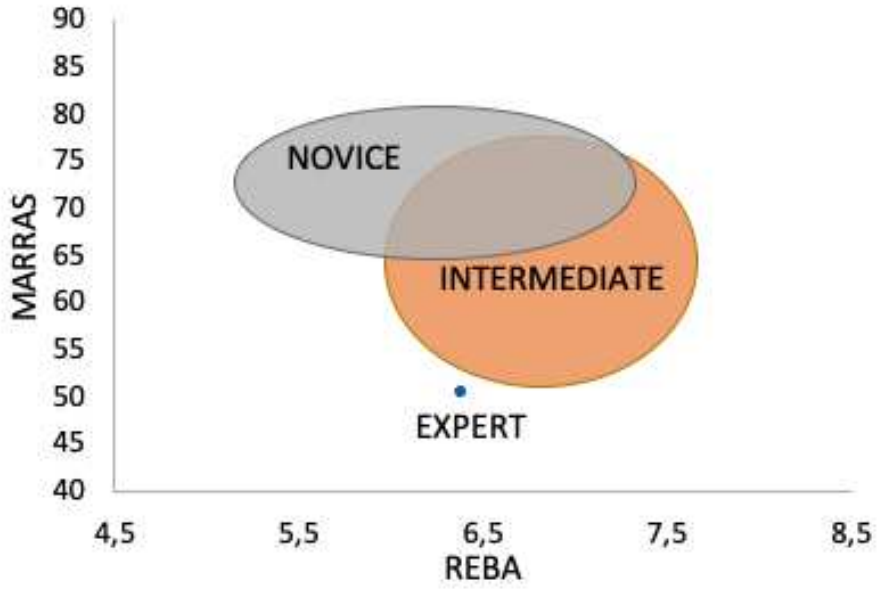

Figure 7. Representation of the statistical regions of membership of the Intermediate and Novice groups, and the corresponding Expert police officer point.

4. Conclusions

The evaluative study focused on the application of police force, specifically centering on Basic Technique 1 within Operational Tactical Procedures (OTP), employed advanced methodologies such as REBA and Marras for the assessment of injury risks. The REBA results revealed that, during the execution of the OTP Technique across various training levels, the maximum scores consistently resided within the spectrum of medium to high-risk levels. Importantly, these scores consistently remained below the maximum risk threshold according to the REBA method. This pattern strongly

suggests that the OTP Technique is intentionally and effectively designed to mitigate injury risks, demonstrating its efficacy across diverse training levels.

Shifting focus to the Marras method, the analysis unveiled a lower probability of high risk in the expert group. The Kruskal-Wallis test further emphasized that medians of high-risk probability differ significantly across training levels. The graphical representation of statistical membership regions vividly showcased these differences between expert, intermediate, and novice groups. This comprehensive evaluation not only highlights the effectiveness of the OTP Technique in injury risk reduction but also underscores nuanced differences in risk probabilities among officers with varying levels of expertise, offering valuable insights for refining training programs and optimizing police force application strategies.

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Institutional Review Board Statement: The studies with human participants were reviewed and approved by the research ethics committee of the University of Granada (no.: 3506/CEIH/2023). Patients/participants gave written informed consent to participate in this study.

Data Availability Statement: Not applicable.

Conflicts of Interest: Not applicable.

Abbreviations

BoB	Biomechanics of Bodies
IESPA	Instituto de Emergencias y Seguridad Pública de Andalucía
IMU	Inertial Measurement Units
OTP	Operational Tactical Procedures
PITS	Physical Intervention Techniques
UOF	Use of force
REBA	Rapid Entire Body Assessment

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