The Influence of Fatigue on Decision-Making in Military Context

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Abstract. Decision making is fundamental in military operations, requiring speed and accuracy in increasingly uncertain scenarios. In such contexts, military personnel face high physical and cognitive demands that can cause fatigue and affect their operational performance. This study analysed the influence of fatigue on decision making in a military context, aiming to optimize performance in demanding situations. A sample of 4th year students from the Portuguese Military Academy was selected. Each participant completed the RP 30 Problem Solving Test, which assesses cognitive abilities essential to decision making, on two different measurement moments. Firstly, the individuals performed a ruck march carrying an approximate load of 30 kg, second, on another day, they completed the test in a resting condition. The data collected on the physiological parameters in the participants, namely heart rate, continuously monitored during the march, enabling calculation of internal load through Training Impulse and also the calculation of the Summated heart rate zone method, as well as changes in the percentage of heart rate reserve. The data was analysed employing various descriptive statistical methods, combined with adequate statistical inference techniques and probability models, using IBM SPSS Statistics 30 and Microsoft Excel software. Two indexes are proposed, the Decision-Making Speed Index and the Decision-Making Performance Index, which quantify, respectively, the speed and quality of decisions under fatigue providing standardized metrics for future studies. The indexes revealed that, when fatigued, cadets experienced a 23,33% reduction in decision-making speed and a 15,09% reduction in decision-making quality. The results demonstrated that fatigue significantly compromises both the speed and quality

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of decision making, impairing several key cognitive abilities. It is concluded that implementing training protocols that combine intense physical effort with decision making tasks is fundamental for deepening understanding as an effective measure to enhance the functional integration of physical and cognitive capacities in order to optimize the operational performance of military personnel, even under exhaustive conditions.

Keywords: Decision Making · Fatigue · Physical Load · RP 30 · Statistical hypothesis tests

1 Introduction

Decision-making can be defined, in a simple and objective way, as the process of analysing several options and choosing the most appropriate one for a specific situation [1]. According to Deveci et al. (2020) [2], the decision-making process comprises the rigorous assessment of environmental factors, integrating a comprehensive perspective, the identification of problems and their potential solutions, promoting an organized analysis that supports the informed choice among the available alternatives.

1.1 Fatigue

Fatigue, as a multidimensional phenomenon, integrates both physical and mental dimensions. The physical dimension is manifested by the reduction of the ability to perform physical efforts. On the other hand, the mental dimension translates into difficulties in terms of attention and the execution of cognitive tasks [3].

The state of mental fatigue corresponds to the brain's response to certain specific behaviours that lead to fatigue as a result of routine repetition. In this type of fatigue, a prolonged specific action decreases cognitive activity, which can result in difficulty concentrating, memory lapses, irritability, and a general feeling of mental exhaustion. While mental fatigue is reflected in reduced ability to focus, loss of motivation, and emotional tiredness, it can also be reflected in reduced physical fitness [4].

The concept of physical fatigue consists of a temporary limitation of muscle capacity to sustain optimal levels of performance, arising as a consequence of prolonged efforts or excessive workloads, and leading to a momentary reduction in the ability to perform physical activities [5]. Physical fatigue can be classified into central and peripheral. Central fatigue corresponds to a limitation in sending signals by the central nervous system to activate muscles, while peripheral fatigue results from failures in the neuromuscular system, which prevent the sustainment of muscle contraction after receiving stimulation from the central system [6]. Additionally recent research has shown that the physical and mental dimensions of fatigue interact in a significant way. In high-demand scenarios, physical fatigue has a direct impact on mental fatigue, namely affecting reaction time in cognitive tasks [7].

1.2 Fatigue in Military Context

Extreme physical and mental demands are often placed on military personnel in their daily lives. The accumulation of these factors can compromise both the individual performance and the functioning of military units, which directly compromises operational effectiveness.

In this context, service members face prolonged periods of intense physical exertion, exposure to adverse environmental conditions, and sleep deprivation. These conditions contribute significantly to muscle fatigue and physical exhaustion in military personnel [8]. In addition, operational demands often impose periods of continuous surveillance and regular shift changes, which result in irregular and insufficient sleep patterns, favouring the development of chronic physical fatigue and compromising performance during operations [9]. Furthermore, fatigue has a crucial impact on the cognitive ability of military personnel thus, when subjected to fatigue, military personnel show a significant reduction in their ability to adapt their decisions to complex and dynamic tactical situations, which leads to a decline in cognitive performance after being exposed to operational stress [10]. The same authors noted that, despite several studies quantify the physical and cognitive decrease resulting from this stress, there is a lack of studies that explore how such changes directly influence decision-making in a military context.

Military personnel are exposed to intense cognitive challenges, such as strategic planning and decision-making under pressure. The impact of cognitive demands on military personnel during various types of foot operations can manifest itself through difficulty concentrating, reduced reasoning ability and increased operational errors, compromising the safety and effectiveness of missions[11]. In addition, the prolonged nature of these operations entails a high workload and frequent sleep deprivation that negatively affect the memory and attention of military personnel, increasing the risk of critical errors in operational environments. Thus, in order to preserve cognitive clarity during such operations it has been suggested that cognitive resilience is critical to preserve operational effectiveness during military operations [12].

It has been reported that intense physical exertion, sleep deprivation, caloric restriction and stress resulting from life-or-death decisions result in significant physiological and psychological changes in military personnel. This set of factors can aggravate the state of fatigue, compromising both the physical and cognitive capacities of service members in combat [13]. Military personnel often face extremely demanding circumstances, and the combination of these factors leads to a significant increase in fatigue and a decrease in operational performance [14].

It becomes essential to constantly monitor fatigue in military settings, as the interaction between physical and mental fatigue can compromise readiness, decision-making, and, consequently, the success of military operations.

1.3 Characterisation of Military Marches

During military operations, walking is a fundamental capability, being a common and physically demanding practice [15]. During training, or even in war scenarios, military personnel are required to move with equipment and supplies, over varied terrain and at different speeds, for prolonged periods [16]. Furthermore, the weight of load

and distances to be covered must be carefully considered in order to maximize the performance of the military in subsequent missions. According to Weyden et al. (2022) [17], this activity can induce not only physical fatigue, but also mental fatigue, and the higher load-to-bodyweight ratio, the more compromised the cognitive function of military personnel will be after marching.

Walking becomes a vital skill for the mobility of service members, preparing them to face adverse and unpredictable scenarios and ensuring the effectiveness of operations. In this context, mobility is an indispensable resource, capable of making a difference on the battlefield [18]. Marching with a load is an essential parameter to assess the tactical preparedness of military forces. However, there is a limited amount of research looking at the impact of these marches on the cognitive ability of military personnel, which could serve to constitute an effective method to monitor fatigue and cognitive performance in operational scenarios [19].

In this sense, fatigue develops progressively over the course of loaded walks, as a consequence of its prolonged and strenuous nature. Fatigue derived from load transport is responsible for significant changes in the physical performance, negatively influencing the mechanics of their movement. These changes increase susceptibility to injury, compromising operational capacity [20].

In addition, carrying loads combined with prolonged physical exertion, compromises the ability to inhibit automatic or impulsive responses in the military, an essential component of cognitive control. The combination of these conditions, observed during loaded gaits, exerts a substantial negative impact on cognitive functions, reflected by a decrease in the accuracy of responses and a reduction in sensitivity to discriminate relevant stimuli. In addition, the increase of the load carried, as well as the frequency of the gaits, intensifies these adverse effects, also increasing the percentage of the heart rate reserve (%HRR) and the rate of perceived exertion of the subjects [21]. Thus, it is possible to identify the existence of a relationship between physical overload and cognitive impairment [19].

1.4 Fatigue vs Decision Making - Decision Time and Quality

The decision-making process often occurs in demanding and complex contexts. In a military context, the physical exhaustion resulting from operations accumulates with cognitive demands, which can compromise the decision-making capacity of individuals. When an individual is cognitively fatigued, it takes longer to make decisions, especially in situations that require adaptation or change [22].

Fatigue has a direct impact on cognitive processing speed, affecting coordination and information processing [23]. Given that cognitive speed is an essential element for effective decisions under pressure, any reduction in this ability can compromise the speed of information analysis and the accuracy of responses in situations that require an immediate reaction. In addition, sleep deprivation or inadequate rest intensify this effect, prolonging reaction time and negatively affecting decision-making [24].

However, in situations of extreme fatigue, individuals tend to adopt compensatory strategies that allow the maintenance or even a slight increase in processing speed, even if this occurs at the expense of a deterioration in accuracy. This adaptation suggests an

attempt to mitigate the effects of fatigue by prioritizing speed, which may result in less rigorous assessments, increasing the risk of error in critical decisions [25].

1.5 Influence of Fatigue in the Decision-Making Process

In highly demanding contexts, the accuracy in the assessment of information and the selection of the most appropriate response can be impaired, increasing the risk of errors and less effective choices. Despite the impact on the speed of decision-making, fatigue also compromises the quality of decisions [26].

Mental fatigue exerts a negative influence on decision-making, leading individuals to adopt a more conservative approach, demonstrating greater risk aversion in the face of uncertainty or potentially risky options [27]. Fatigue can also reduce emotional control and the ability to assess risks, which results in a distorted perception of the risks and benefits associated with different alternatives, thus compromising the quality of the decision [28]. This phenomenon is characterized by a gradual reduction in motivation, particularly in contexts that require intense and continuous cognitive effort. This state compromises essential skills for operational effectiveness, such as the management of cognitive functions, negatively influencing the execution of complex tasks. Its effects are more pronounced on controlled cognitive processes, also known as top-down processes, which concern voluntary mental operations, such as planning, evaluation of alternatives, logical reasoning and conscious decision-making [29].

Recently, Brady et al. in [30] point out, fatigue can also impair decision-making by reducing attention and increasing the propensity for error. At the same time, it may lead to a decrease in cognitive flexibility and the ability to adapt to new information and scenarios [30]. Thus, it is essential to deepen the analysis of the influence of fatigue on decision-making in a military context, contributing to clarify the effects of this phenomenon on operational performance.

1.6 Document Structure

This work is structured as follows: Sect. 2 describes the objectives and the methodology applied; the data, the results analysis and discussion will be presented in Sect. 3, and, finally, conclusions and final remarks close the document in Sect. 4.

2 Objectives and Methods

2.1 Objectives

The main objective of the present research consists of "Analysing the influence of fatigue on decision-making in a military context, in order to optimize operational performance in demanding contexts".

Following this general objective, the hypothesis by research question: "What is the influence of fatigue on decision-making in a military environment?". This question guides the structuring of the research, configuring itself as the central question that sustains the analysis of the phenomenon under study.

Furthermore, we aim to understand the physiological impact of a loaded march on the military personnel and to what extent does fatigue interfere with the speed and quality of decision-making?

Participation in the study was preceded by obtaining a written informed consent, in accordance with the ethical principles of scientific research with human beings. In this context, the participants were presented with the objectives of the research, as well as a detailed explanation of the activities to be carried out, including what would be asked of them, the estimated time of participation and the place of data collection. Information was also provided regarding the processing of the data collected, namely the guarantee of confidentiality and anonymity, as well as the procedures for storing and preserving the information. Additionally, it was made explicit that participation was entirely voluntary, and participants could refuse or interrupt their collaboration at any time, without any prejudice or penalty.

2.2 Experimental Protocols

The Problem-Solving Test (RP 30) is an instrument designed to assess cognitive speed and flexibility [31]. It consists of 30 items that require the mobilisation of multiple cognitive abilities. Each item requires interpreting logical relationships within a graphical structure to determine whether specific conditions are met, with difficulty increasing progressively. The task engages core components of intelligence, including reasoning, spatial ability, numerical ability, and memory. The total score obtained in the Portuguese adaptation of the RP-30 ranges from -79 to 71, demonstrating high discriminative capacity and suitability for detecting variations in cognitive performance, particularly those associated with fatigue [31]. Regarding psychometric properties, the internal consistency of the instrument ranges between .91 and .95, indicating a very high level of reliability. These values suggest strong homogeneity among items and high precision in measuring the construct under assessment [32].

2.3 Loaded March Protocol

The activity of walking with load was carried out on May 6, 2024, at the Portuguese Military Academy - Amadora Campus, with the aim of inducing physical fatigue in the participants, constituting the first moment of data collection of the present research. The course consisted of four consecutive laps of a previously defined route, with two kilometres (km) per lap, totalling 8 km. A positive accumulated difference in altitude of approximately 125 m was estimated along the route. The lap structure allowed a more effective control of the participants during the exercise, ensuring the uniformity of the procedure. Throughout the march, the participants carried a total load of 30 kg, consisting of a 20 kg backpack (fully loaded), an FN SCAR-L automatic rifle (3,4 kg) and other individual equipment, namely uniform, boots, helmet, combat belt, tactical vest and hydration system. The hydration system consisting of a flexible reservoir (2 l) carried on the back and connected to a tube with a valve, allowing water to be ingested while walking without the need to stop. The uniformity of the load carried by the participants was guaranteed by prior weighing using a suspension scale, an instrument suitable for measuring the total weight of the individual equipment. This procedure allowed to

ensure the standardization of the conditions of physical exertion imposed during gait, contributing to the internal validity of the study.

The march took place under a self-imposed maximum effort regime, with the participants being given the guidance to complete the course at the highest speed they could maintain. This approach allowed adjusting the effort to the individual physical capacity, inducing different levels of fatigue, in coherence with the objectives of the study. After the last lap, the participants immediately moved to a room where the RP-30 cognitive test was performed. This final displacement was integrated into the protocol in order to ensure that the cognitive test was applied under the direct effect of accumulated physical fatigue.

In order to ensure safety and control of the procedure as well as reliability of monitoring, participants were organised into four groups. HR was continuously monitored using a Polar H10 chest strap, connected to the Polar Flow app, both developed by Polar Electro Oy (Kempele, Finland), using each participant's personal smartphones.

2.4 RP-30 Test Protocol

The RP-30 test was administered at two distinct time points: the first immediately after a loaded march, under fatigue conditions, and the second under resting conditions. Both administrations took place in a classroom setting, ensuring consistency of environmental conditions. Under fatigue conditions, as participants completed the march at different times, the test was administered individually, immediately upon each soldier's arrival. The execution time was recorded separately for each participant, ensuring procedural standardisation. Under resting conditions, defined by the absence of relevant physical activity on the same day, the test was administered collectively, with a single start and end time for all participants. In both conditions, the instrument was administered in paper-and-pencil format under the supervision of psychologists from the Psychopedagogical Support Section of the Military Academy.

2.5 Physiological Load Indicators

2.5.1 Heart Rate Reserve

With regard to internal load, heart rate (HR) is widely recognized as the method of choice for its quantification [33], allowing a continuous assessment of the intensity of physical effort and the physiological response of the body throughout the different phases of the activity. Derived from this parameter, the heart rate reserve (HRR) is a relevant measure for the assessment of internal load, showing significant positive relationships with variables associated with the volume and intensity of the effort performed, such as the distance travelled, reliably reflecting the physiological response to effort. HRR results from the difference between maximum heart rate (HR_{max}) and resting heart rate (RHR), serving as a basis for calculating %HRR [34], used as an indicator of the relative intensity of exertion as a function of individual ability [35].

2.5.2 Edwards Training Impulse (TRIMP) – Summated Heart Rate

The method we used to quantify internal training load is the summated heart rate zone (sumHR) model, proposed by Edwards (1993) [36]. This model, developed from the TRIMP concept, calculates the physiological load based on the time spent in different HR intensity zones. One of the main advantages of Summated Heart Rate (sumHR) is its ability to proportionally reflect the increase in physiological stress associated with higher intensities, by assigning progressively higher weights to higher HR zones. This characteristic allows a more accurate assessment of the physiological impact of exercise. In a military context, sumHR proves to be a valid and effective tool for monitoring the training load, allowing a practical and rigorous assessment of the physiological demand inherent to military activities [37].

The sumHR model, also known as Edwards' TRIMP, described in Table 1, defines five intensity zones based on HRmax percentages, associating each of them with an increasing level of physiological intensity and a proportional weighting factor [38].

Table 1. Intensity zones of the Edwards' TRIMP (sumHR)

$\%HR_{max}$	Weighting Factor	Exercise Intensity
50 – 59%	1	Very Low
60 – 69%	2	Low
70 – 79%	3	Moderate
80 – 89%	4	Hard
$\geq$ 90%	5	Very Hard

2.6 Decision Making Indicators

The objective of this study is to contribute to addressing an existing gap in the Portuguese Army regarding the relationship between physical fatigue and cognitive performance in an operational environment. Through the implementation of experimental protocols and the articulation between objective physiological indicators and cognitive performance data, it is possible to assess, in a controlled manner, the effects of fatigue on decision-making.

For this purpose, two indexes are proposed, the Decision-Making Speed Index and the Decision-Making Performance Index, which quantify, respectively, the speed and quality of decisions under fatigue providing standardized metrics for future application, which represent a methodological approach that allows direct comparison between the two experimental states, thereby enhancing the ability to identify the effects of fatigue on cognitive performance and promoting the adaptation of decisions to physical and mental states.

2.6.1 Decision-Making Speed Index

The ratio between the median value of responses obtained (MRVO) and the maximum number of possible responses (30) is considered to define the Decision-Making Speed Index (DMSI), computed under the fatigued condition and in the resting condition by:

$$DMSI = \frac{MRVO}{30} \times 100\%$$

This DMSI index allow to measure the impact, in percentage points, on military performance in terms of decision-making speed when under fatigue.

2.6.2 Decision-Making Performance Index

The ratio between the mean score obtained (MSO) in the RP-30 test and the maximum score that can be obtained in the test (71), is considered to define the Decision-Making Performance Index (DMPI), computed under the fatigued condition and in the resting condition by:

$$DMPI = \frac{MSO}{71} \times 100\%$$

This DMPI index provides an indication of the performance attained as a percentage of the maximum possible score in the test.

2.7 Statistical Methodology

A sample of 4th year students from the Portuguese Military Academy was selected from the Military Academy cadets at the Military Academy, who are physically and cognitively prepared to perform demanding tasks. It consists of 36 cadets who voluntarily participated in this study, composed exclusively of male military personnel, as a methodological approach designed to ensure the homogeneity and representativeness of the sample. The chosen group was selected for its suitability to the research objectives, as it provides the conditions required to analyse the influence of fatigue on decision-making in a military context.

The protocol implementation was carried out at two different moments, in May 2024, the RP-test after an 8km loaded march (with fatigue) and in June 2024, the RP-30 test (without fatigue), in order to safeguard the independence of the measurements and, consequently, the internal validity of the results.

This is a quantitative study as it uses information collected in the field, based on a previously defined sample of soldiers, considering standardised information collection instruments as sources of analysis. The data collected were structured and statistically analysed using IBM SPSS Statistics 30 and Microsoft Excel software, exploring the relevant variables [39]. The data was analysed using various descriptive statistical methods, combined with adequate statistical inference techniques. In order to compare the results of the RP-30 test in two conditions (with and without fatigue) in two aspects, speed and quality of decision-making, parametric hypothesis tests were used to analyse differences in the mean population parameter by implementing Student's t-test [39],

with a significance level of 10%. The assumption of normally distribution of the data was verified using the Kolmogorov–Smirnov test. Levene's test was also considered to evaluate homogeneity of variances [40]. If the necessary assumptions were not verified, non-parametric statistical methods for hypothesis testing (median population parameter) were also implemented to compare the results in the two conditions under analysis, considering the Mann-Whitney test [39].

3 Results Analysis and Discussion

The participants have been chosen among the Military Academy students who have been considered suitability to the research objectives and constitute a representative sample. A sample of 36 students of 4th year from the Portuguese Military Academy was selected. The participants were between 21 and 30 years old with an average of 23 years and a standard deviation (sd) of 2,2 years. Weight was between 62 kg and 95 kg, with an average of 78,14 kg and a sd of 7,63 kg; The height of the subjects ranged from 1,65 m and 1,92 m with an average of 1,78 m and a sd of 0,07 m. In terms of body mass index (BMI), lies between 18,51 kg/m^2 and 28,68 kg/m^2 with an average of 24,56 kg/m^2 and a sd of 2,02 kg/m^2 (Table 2).

Table 2. Characteristics of the participants

Statistics	Age (years)	Heigh (m)	Weight (Kg)	Body mass index
Minimum	21	1,65	62	18,51
Mean	23	1,78	78,14	24,56
Standard deviation	2,2	0,07	7,63	2,02
Median	22	1,78	77	24,52
Maximum	30	1,92	95	28,68

Each participant completed the RP 30 Problem Solving Test, which assesses cognitive abilities essential to decision making, on two different measurement moments. Firstly, the individuals performed a ruck march carrying an approximate load of 30 kg, second, on another day, they completed the test in a resting condition. The data collected on the physiological parameters in the participants, namely heart rate, continuously monitored during the march, enabling calculation of internal load sumHR Zone method, as well as changes in the %HRR.

3.1 Internal Load Analysis Using Edwards TRIMP

The Edwards sumHR model, was used to estimate the internal load, based on the physiological response to exertion. The median is 269 arbitrary units (a.u.) com values ranging from a minimum of 112 a.u. to a maximum of 318 a.u. The average load recorded was 263 a.u., with a standard deviation of 40,37. The interquartile range is between 241 a.u. (Q1) and 293 a.u. (Q3), with a lower atypical value (112 a.u.).

In addition, the distribution of time (min) by the intensity zones defined in the Edwards model was analysed, as shown in Fig. 1. It was found that 50,6% of the total march time was spent in zone 4 (1172 min), while 31,95% of the time was spent in zone 5 (740 min). Together, these two zones, associated with high intensities, represented approximately 82,58% of the total time recorded. Zone 3, associated with moderate intensity, corresponded to 12,82% of the total gait time (297 min). Zones 1 and 2, associated with low intensities, together accounted for 4,62% of the total accumulated time (28 min in zone 1 and 79 min in zone 2).

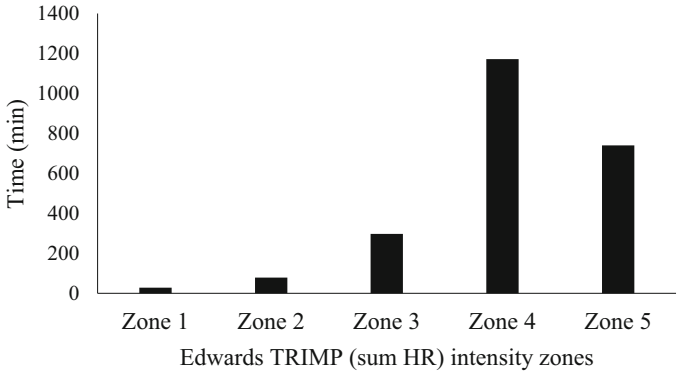

Fig. 1. Intensity zones distribution during the loaded march

3.2 %HRR Monitoring During the Loaded Military March

The distribution of %HRR over the 72 min of the loaded march is represented in Fig. 2, using box-plots each one corresponding to each min of the activity. This time interval was defined based on the time spent by the participant who took the longest to complete the course, thus allowing a complete analysis of the entire sample. Each boxplot illustrates the interindividual variation of %HRR in each min, making it possible to follow the evolution of the intensity throughout the exercise.

In general, there is a tendency for %HRR to stabilize at high values during most of the walk, reflecting the maintenance of a consistent exertion. However, the data show considerable variability among participants, with fluctuations that reach maximums above 100% and minimums below 50%, indicating moments of greater and lesser intensity. It is important to note that, at the end of the graph, there is a progressive decrease in %HRR, which does not represent the entire sample, since these datapoints correspond only to participants who were still on the march. This reduction may therefore convey an incorrect impression of a decrease in intensity in the final phase, when in reality it reflects the lower representativeness of data at these moments.

The overall median %HRR was 82,88%, with a minimum value of 43,60% and a maximum of 103,42%, which shows a predominantly high cardiovascular intensity, but with significant oscillations between individuals.

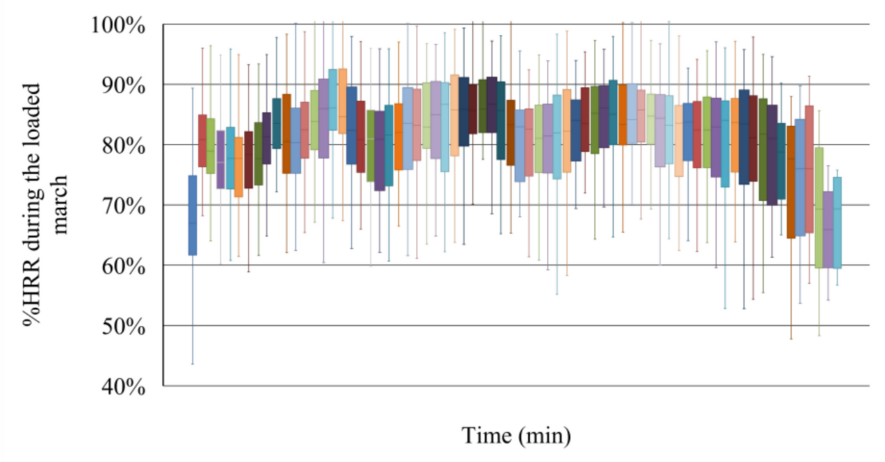

Fig. 2. Distribution of %HRR during the loaded march

3.3 Decision-Making Indicators

This study objectively reflects comparisons between the proposed experimental conditions, by means of the Decision-Making Speed Index and the Decision-Making Performance Index, that are implemented and analysed constituting a useful tool that consider the RP-30 test to quantify the impact of fatigue on decision-making.

3.4 Decision-Making Speed with and Without Fatigue

In the speed analysis, the variables number of responses given without fatigue (X_1) and number of responses given with fatigue (X_2) were considered and are represented in Fig. 3. It was observed that, under fatigue condition, participants demonstrated a reduction in the median number of responses provided during the RP-30 test. All participants completed the test within the same time frame (17 min), indicating that this difference reflects a decline in performance under fatigue. Under non-fatigued conditions, the median number of responses was 27, with a minimum value of 13 and a maximum value of 30, with a mean of 25,69 and a standard deviation of 4,65 with 50% of participants providing between 23 and 30 responses. On the other hand, after undergoing the load march, the median number of responses obtained was 20, with values ranging from 11 to 30, a mean value of 20, with a standard deviation of 5,33. In this case, 50% of participants providing between 17 and 23 responses on the RP-30 test, gradually lower in the fatigue condition when comparing the two conditions.

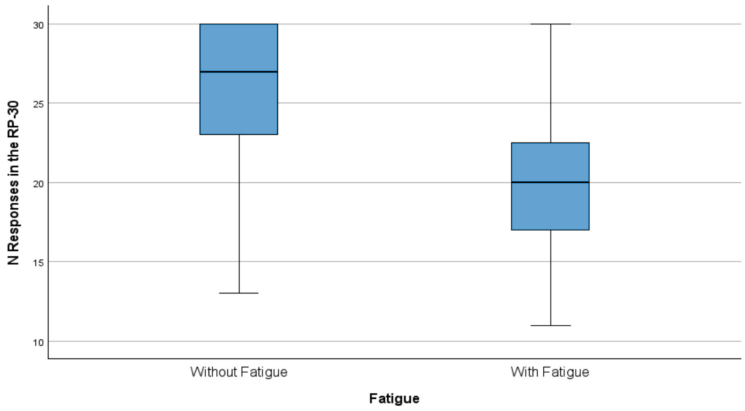

Fig. 3. Boxplot relative to N. of Responses in the RP-30 Test with and without Fatigue

According to the study objective, and taking into account that the assumption of normality for the distribution of the variables under study has not been satisfied is considered the null hypothesis, H0: The medians are the same across the proposed experimental conditions, under fatigue condition and non-fatigued condition are compared; this allows an evaluation of the fatigue and non-fatigue conditions in terms of the number of responses provided during the RP-30 test. Resorting to Mann-Whitney test, the null is rejected ($U = 278{,}5$, p-value $< 0{,}001$), therefore significant different results for the RP-30 test are provided depending on the experimental condition.

Consequently, the value obtained for the Decision-Making Speed Index was 90% under non-fatigued condition and 66,67%, under fatigue conditions, the DMSI was 66,67%. This index revealed that, when fatigued, participants experienced a 23,33% reduction in decision-making speed.

3.5 Decision-Making Quality with and Without Fatigue

Regarding decision quality, taking into account the Direct Score (DS) in the RP-30 test, the variables DS without fatigue (Y_1) and DS with fatigue (Y_2) were analysed and are represented in Fig. 4. Under non-fatigued condition, the DP scored mean of 39,48, with a standard deviation of 7,09, with a sample range of 25,74 (minimum of 24,96 and a maximum of 50,7). The median value was 39,39, obtain the values of 45,04 and 32,95 for the third and first quartiles, respectively. When experiencing fatigue, the mean score decreases by 10,71 points, reaching a value of 28,77, with a standard deviation of 8,50.

50% of participants scored between 33,345 and 23,595 in the direct scores of the test, with a median value of 39,39. Overall, it can be observed that, under fatigue conditions, there was a decrease in the DP achieved in the RP-30 test.

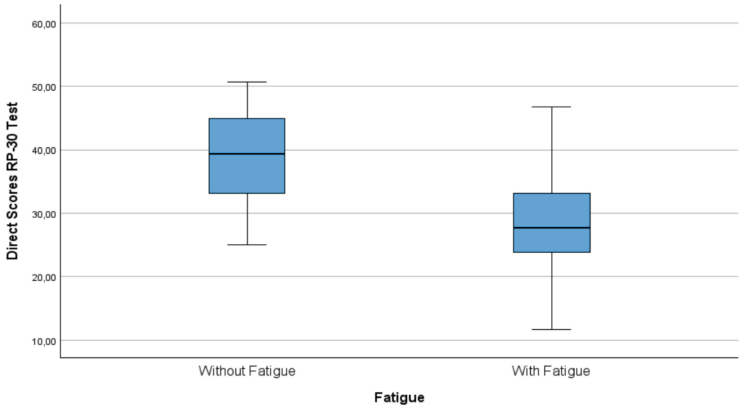

Fig. 4. Boxplot relative to Direct Scores on the RP-30 Test with and without Fatigue

From the perspective of the DP scored variables, to compare PD under non-fatigued and fatigued conditions, the differences in the means of the variables were analysed, by applying Student's t-test. The required assumptions were verified. The Kolmogorov-Smirnov test indicated that the variables Y_1 and Y_2 can be considered to originate from a normal distribution ($p > 0{,}200$). Furthermore, using Levene's test, the homogeneity of variances for variables Y_1 and Y_2 was established ($p = 0{,}532$). The application of Student's t-test ($t = 5{,}802$; $p < 0{,}001$) led to the rejection of the null hypotheses of equal expected values, concluding that the mean DP score is significantly lower under fatigue than in the non-fatigued condition.

The Decision-Making Quality Index, which reflects the performance achieved as a percentage of the maximum possible score in the test, in the non-fatigued condition is 55,61%, after the march, this value declines to 40,52%, representing a difference of 15,09 percentage points between the two conditions. The DMQI index revealed that, when fatigued, participants experienced a 15,09% reduction in decision-making quality.

4 Conclusions and Final Remarks

Decision-making in a military environment is a central process for the success of operations, requiring speed, precision, and the ability to adapt to scenarios marked by uncertainty, time pressure, and high complexity. In these contexts, military personnel are often exposed to intense physical demands, such as prolonged loaded marches, which can lead to states of physical and cognitive fatigue. This functional state, resulting from the combination of these forms of fatigue, is characterized by a decrease in the availability of mental resources, compromising the effectiveness of the processes of perception, attention, memory and reasoning as essential pillars for effective decisions in critical situations.

These results demonstrate that fatigue compromised the military's ability to maintain structured reasoning, analyse alternatives, and respond accurately, directly interfering with higher cognitive functions associated with decision-making.

The results obtained in this study contributed to fill an existing gap in the context of the Portuguese Army with regard to the relationship between physical fatigue and cognitive performance in an operational context. The construction of the DMSI and DMPI indexes represented a methodological approach that enabled a direct comparison between the two experimental states. These instruments may be useful in future studies that aim to integrate physiological and cognitive variables, especially in applied contexts. Based on the data obtained, measures with potential for practical application are also identified. In this sense, the importance of preparing service members to make decisions in conditions of fatigue is highlighted, through exercises that combine intense physical effort with situations that require information evaluation, choice between alternatives, or decision-making under pressure. More than just training resistance to effort, it is important to develop the ability to recognize the effects of fatigue on cognitive performance, promoting the adaptation of decisions to altered physical and mental states. This approach reinforces the functional integration between physical and cognitive capacities, contributing to a more effective performance in demanding operational contexts.

Notwithstanding the contributions of the present study, it is important to recognize its limitations. The sample consisted exclusively of male military personnel, in a methodological decision aimed at ensuring physiological homogeneity and controlling variables influenced by gender, such as differences in body composition, response to physical exertion and exercise tolerance.

For future research, it is recommended to broaden the sample to female military personnel, in order to allow a comparative analysis between genders and to assess possible differences in the response to fatigue. It is also suggested to increase the sample size, in order to strengthen the statistical power of the analyses and allow more refined segmentations. Finally, it is proposed to explore the relationship between different levels of physiological fatigue and performance in decision-making, with a view to deepening the knowledge about the gradual effects of fatigue on critical cognitive functions in an operational environment.

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