Computerized Predictive Analysis of Accidents (FOCOS/PRONTOS System): Study of Rare Cases

Valmin Ramos-Silva [a*], Marcela Souza Lima Paulo [b,c], Wallysson Francis Soares, Me [c,d++], Jamile Pratti Orlandi Cabral [b#], Elisa Smith Barbiero Medeiros [c,b] and Thais Costa Jesus [c,e†]

[a] *State Department of Health, Espírito Santo, Vitória, Brazil.*
[b] *School of Health Sciences of Santa Casa de Misericórdia de Vitória - EMESCAM, Faculty of Medicine, Vitória, Brazil.*
[c] *Science, Technology, and Innovations in Mental Health and Quality of Life" Research Group - EMESCAM, Vitória, Brazil.*
[d] *State University of Campinas - Unicamp, São Paulo, Brazil.*
[e] *Psychology Division of the HC at the Faculty of Medicine, The University of São Paulo -USP, Brazil.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

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[++]*PhD Candidate;*
[#]*Master's Student;*
[†]*Neuropsychology Specialist;*
Corresponding author: E-mail: gpcienciatecsm@gmail.com,valmin.silva@gmail.com;

ABSTRACT

Introduction: We report here a series of ten rare cases of work accidents that occurred in five Brazilian companies using the Computerized Evaluation of Work Readiness (FOCOS/Prontos System), aiming to assess the correlation between instrument performance and factors influencing the accidents.

Materials and Methods: Before joining the company, employees access the system with a login and password, and in less than a minute, they perform the test, which consists of identifying pre-known figures as correct or incorrect. The test assesses impulse control (the ability to avoid errors by touching during the evaluation), attention (discriminating the figure that represents the correct stimulus in the test and reacting as quickly as possible by touching the screen every time it appears), and reaction time (speed to react to the correct stimulus by touching the screen). The test result is immediately released after its completion. The test result contributes to work clearance, referral for medical or psychological evaluation, or activity suspension.

Results: The ten cases occurred in 2022 and early 2023, equally distributed across morning, afternoon, and night shifts. In the 300 readiness evaluations, 218 alterations associated with impulse control (66), attention (39), reaction time (40), concentration (27), and risk predictor (46) were identified. The average deviation level was 80.1±22.62%, ranging from 27% to 100%, with a median of 88.5%. The main reasons for reporting deviations were falls from heights (leading to death), improper activity performed in restricted areas (leading to death), collisions with heavy vehicles (6 cases), upper limb injuries (1), and fire (1). Two fatalities occurred.

Conclusion: The Computerized Test for Readiness Evaluation (FOCOS/Prontos System) as a risk assessment tool identified alterations in readiness parameters in 100% of the workers involved in the analyzed cases, demonstrating its predictive capacity in identifying accident risks.

1. INTRODUCTION

We report here on a series of ten rare, spontaneously reported cases of occupational accidents by five companies using the Computerized Work Readiness Assessment (FOCOS/Prontos System) in order to assess the correlation between performance on the instrument and influential factors in accidents, seeking to confirm the predictive ability of the tool in identifying the risk of occupational accidents in the case series in question.

The relevance of reporting the cases is due to the early detection of risk patterns, due to the costs associated with serious and sometimes fatal events, bringing immeasurable material losses to companies and psychosocial losses to the worker. Although there are currently computerized tools that can identify predictive variables capable of detecting silent physical, cognitive, and psychological signs that can detect employees at higher risk, accidents remain a reality due to their multifactorial nature, which can arise from the combination of various particularities, not only from human and behavioral factors, but also environmental, operational, and socio-occupational factors, among others. The answer may lie in utilizing tools that enable the integration of multiple data from the multifaceted conditions that influence the accident, striving for greater accuracy in prediction. Variables organized in contingency tables and analyzed statistically, even in the absence of a clear prior hypothesis to test, can identify employees at immediate risk of accidents [1].

In this sense, the Computerized Work Readiness Assessment (FOCOS/Prontos System) identifies unsafe behaviors, emotional states, decreases in attention, impairments in concentration, sleep or fatigue issues, and other factors that can lead to accidents. Despite these available technologies, there are still reports of undesirable health and work-related events such as head injuries, eye injuries [2], sprains, strains, stretching injuries, extremity and soft tissue skin injuries [3,4], deaths and injuries from fires and explosions [5] falls from heights and heavy vehicle accidents, which can be fatal [6,7].

There is evidence of multiple factors contributing to unsafe workplaces, including unsafe conditions, technical factors, complexity of the site structure, and unsafe human behavior [8,9]. Some of the causes attributed to these issues are mental fatigue from stressful work

environments, excessive time and workload demands, abuse of alcohol and other drugs, negative attitudes towards work, and managerial errors in decision-making that increase risk-taking behavior; irregular sleep patterns, loneliness, and distraction from interactive automotive technology interfaces [10-15]. Another factor is heat stress and difficulty in evaluating biometric signs and thermophysiological constraints, implicated as being among the factors that increase vulnerability to accident and injury risks during work [16].

Therefore, considering all the factors involved in the genesis of accidents and in reducing harm, it is necessary to invest in knowledge, development of certified modern technologies and skills to handle the challenges in addressing the central issues in the modern world of work [17]. In this confrontation it is necessary to employ strategies that prioritize improving competence and knowledge; employing technological tools; investing in verifications and audits; and obtaining recognition and certification to help design and implement appropriate barriers that prevent the propagation of unexpected events, facilitated by the failure of managers and workers to watch out for their own safety or by the misinterpretation of rules that should value not only mistakes, but also successes within the variability of daily performance in complex work systems [18,19].

In this sense, this study aimed to investigate whether the Computerized Work Readiness Assessment, identified some of the variables predictive of accidents in the workers evaluated. To that end, we sought to analyze the FOCOS/Prontos System, an instrument widely used by different populations in more than 100 companies from different industries such as mining, steel, logistics, transportation, among others, mostly located in Brazil, but also with adaptation for other countries. In use for more than 15 years and with documented records, the system has already been applied on thousands of people, with a database of millions of assessments [20]. As a result of its broad recognition and satisfaction of the user companies according to publications and awards achieved [21], it stood out as a pioneer tool, which is why it was chosen to be the object of this study.

2. METHODOLOGY

Before starting the day's work, the employees mapped according to criteria established by each

organization access the system with their own login and password, and in less than a minute, perform the assessment using a procedure that is repeated constantly every day they work, establishing itself as part of the organization's safety culture, as another piece of Personal Protective Equipment (PPE). In some organizations, the assessment is repeated during the workday, hours after the first application, in order to analyze possible effects of the work hours, especially those of long duration or those involving monotonous activities.

The computerized readiness and attention test (FOCOS/Prontos) used in this study was developed by Cabral based on the *Continuous performance tests* (CPTs) [22,23,24]. "FOCOS" [25] (or "Computerized Occupational Health & Safety Tools", in English) is an acronym that alludes to "focus", while "Prontos" [26] (or "Ready"/"Readiness", in English), is the 10th version of the system and latest innovation of the tool.

During the performance of the test, alternating figures appear on the screen, one marked as the "*correct of the day*" and the other as "*incorrect*", based on the CPT. During the assessment, the system evaluates more than 200 variables, which are translated in sub-parameters that can be summarized in four main pillars, for the purposes of understanding in an illustrative way: 1. *impulse control* (cautious decision making, focusing on the correct stimulus, measuring the ability to avoid error); 2. *attention* (discriminate, in the test, the figure that represents the correct stimulus and react as quickly as possible, without omission of response); 3. *reaction time* (speed to react to the correct stimulus); and 4. *concentration*(maintaining focus and attention throughout the evaluation, with consistent control of the answer time). In addition, the system is able to differentiate between *unsafe behavior*, which can be a result of deliberately performing the procedure incorrectly or simply a lack of attention to memorizing the correct stimulus of the day, both of which are common causes of accidents.

The system's methodology does not only analyze the aforementioned parameters independently, but also the relationship between them, the temporal fluctuations that suggest changes in behavior, and other factors that indicate risk tendencies. The algorithm, based on machine learning techniques, then also generates a global parameter called 5, "risk predictor," which aims to

identify whether the performance displayed by the individual correlates to risky behaviors that form the methodological basis, in data that continuously feeds back as individuals repeat assessments daily – which, in turn, generates no learning effect given its dynamic and random characteristic.

It is also worth mentioning that the evaluation is simple and objective, making it intuitive and easy to understand for different audiences, with no schooling requirements, and was even applied to elderly patients in its conception and initial studies. Additionally, it does not depend on factors that could influence performance, such as numbers, letters, colors, and other associations that require complex brain functions – that is, it is fully adapted to socioeconomic and cultural patterns, as can be confirmed by its use in different territories of Brazil and abroad [20].

The user and their immediate supervisor are informed of the results, according to flows defined by the organization and the rules and limits of the legislation, immediately at the conclusion of the evaluation. Regarding the computational method analyzed here (FOCOS/Prontos System), it is important to consider that it is a technological tool certified in internationally recognized standards such as ISO 27001, and it has also been audited by renowned companies specialized in technologies and Information Security.

For adaptation and familiarity with the tool, the first six evaluations, which comprise the habituation phase, are disregarded; and in the full, individual evaluation, the last 30 valid tests are taken into account, which then form a moving average.

Once the evaluation is completed, the employee is released to carry out the day's activities or, if the results of the evaluation are altered and meet the organization's parameters, the supervisor will approach the employee and decide whether to allow them to work after discussing the procedure, observing their behavior, and providing assistance throughout the day. The supervisor may also suspend or reassign the risky activity, or if there is an available department in the company, refer the employee to health services (internal medical evaluation or the company's health team, and if necessary, external evaluation) where they will receive guidance or a specific referral to investigate potential hypotheses.

In these flows, among the clients who use the tool, physical or emotional health conditions were found, and the methodology supported the subsequent diagnosis of cases of visual acuity impairment, hormonal impairment that impacted sleep quality, signs of fatigue, and other emotional impacts, such as suicidal ideation and grief processes, among others.

At the end of the evaluation, the system generates a chain of information for the company, which can be delivered via different notifications and alerts for more immediate decision making of the leaders, but which are also available in the history of the dashboards provided or in confidential reports. The immediate actions intend to protect the individual, valuing life above all else. In case of accidents, the company sends the case report to the consulting company, which then issues a technical report based on the variables and sub-variables presented in the methodology and some descriptive elements, compiled from the information generated by the system, in order to contribute to the understanding of the accident's genesis and the creation of educational and preventive action plans, presenting the indicators that were issued in the evaluation of the individual(s) involved in the accident. The report issued by the consulting company contains the following structure, issued automatically by the system, with the compilation of the following information: Company name, date and time of occurrence, detailed description of the accident (when provided), Time interval between the "last test" and the occurrence of the accident and its association with the variables indicative of prevention, from the last 30 evaluations, including the parameters (sub-variables) mentioned above and possible complaints spontaneously reported by the individuals, such as malaise, sleep, pain, controlled medication, anxiety, depression, family, financial and work difficulties, and alcohol use.

We contacted the companies that use the system, and we got a return from five companies, which totaled 10 recent cases of rare accidents and that met the need to present complete information to enable comparison between cases, to verify the prediction of accidents by the Prontos System's methodology, a tool that in addition to providing the opportunity to remove the risk, also seeks the self-development of the employee, increased safety perception, the development of leadership and the strengthening of communication bonds in the organization.

The information contained in the technical report issued by the consulting company was analyzed in the SPSS software, version 21.0, to obtain the descriptive statistics presented, in absolute numbers and percentages, mean, median and standard deviation [27].

3. RESULTS

The ten cases were reported in the year 2022 and in the first two months of 2023, in spontaneous reporting by five companies. The occurrences were reported between the hours of 6:30 am and 11:30 am (morning [3/30%]); 3:00 pm and 4:30 pm (afternoon [3/30%]), and 00:00 am and 02:30 am (evening [3/30%]) and in one case the time of the accident was not informed. In the score of spontaneous reports of well-being from the last 30 evaluations, there were two complaints about malaise and financial difficulty, and no complaints about sleep, pain, controlled medication, anxiety, depression, family difficulty, work difficulty, or alcohol use.

In the readiness assessment, alterations in the parameters impulse control, reaction time, attention, concentration, and risk predictor were identified in the last 30 assessments in each of the ten reported cases, as described in Table 1.

Once the parameter changes were identified and according to the parameterizations of each organization, the Prontos System made the daily action suggestions, preceding the reported occurrences with preventive and/or restrictive actions, some of these with a recommendation to remove from risk in more than 60% of the total tests applied in the 30 days, for the same employee, as described in Table 2, case 3.

The mean of the deviation levels observed in the ten occurrences was 80.1±22.62% ranging from 27 to 100% and a median of 88.5%. The main reasons for deviation notifications were due to falls from height (leading to death), activity performed improperly in a restricted area (leading to death), collision with a heavy vehicle (6 cases), injury to the left hand phalanx during equipment handling, and fire due to oil leakage during maintenance of a slag ramp, as described in Table 3.

Table 1. Altered readiness parameters of the ten injured employees, considering the last 30 evaluations prior to the occurrence, in the five companies participating in the Readiness Assessment Program (FOCOS/Prontos system), in 2022 and 2023

Altered parameter	Total	Case Identification (Frequency)									
		01	02	03	04	05	06	07	08	09	10
Impulse control	66	10	1	10	5	7	11	-	1	3	18
Attention	39	5	6	3	3	1	2	7	5	6	1
Reaction time	40	9	-	-	-	1	5	6	19	-	
Concentration	27	3	1	4	1	3	-	3	2	10	
Risk predictor	46	2	-	13	12	8	4	-	-	-	7
TOTAL	**218**	**29**	**8**	**30**	**21**	**20**	**22**	**16**	**27**	**19**	**26**

Table 2.Suggested actions from the Prontos System and percentage of deviation (parameters outside of the normal range), based on the last 30 evaluations conducted on the ten accidents in five companies participating in the Readiness Assessment Program (FOCOS/Prontos System) in 2022 and 2023

Suggested action	Total	Case Identification (Frequency)									
		1	2	3	4	5	6	7	8	9	10
Suspend risky activity and/or redirect	**38**	3	2	16	4	3	3	3	2		2
Refer to medical or psychological care	**11**	-	-	3	3	-	1	1	-	3	-
Unsafe behavior	**10**	-	-		6	-	2	2	-		-
Observe behavior	**26**	10	2	-	5	-	2	2	-		5
Monitor and guide good habits	**5**	-	-	-	-	-	-	-	-	5	-
Approach for safety dialogue	**126**	16	4	11	9	17	16	-	25	9	19
Release for work	**84**	1	22		3	10	6	22	3	13	4
Total	**300**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**

Table 3. Percentage of the level of deviation and description of the causes for the ten occurrences reported by companies participating in the Readiness Assessment Program (FOCOS/Prontos system) in 2022 and 2023

Case	Description of the accident	Deviation Level
01	Fatal accident occurred due to a fall from a height of 12 meters.	97%
02	An individual performed an activity in a restricted area without having the proper authorization, which resulted in death.	27%
03	The driver was on their way to repair a drill, and when they returned from the workshop in the early hours of the morning, they passed close to a wooded area, damaging the truck's rear Cardan axle.	100%
04	An injury occurred to the tip of the little finger on the left hand due to the handling of a shaft placed in a bench vise while disassembling a gear from a reducer. A bearing located at the end of the shaft came loose, resulting in the accident.	90%
05	During interstate transportation, there was a side collision of a piece of equipment with the column of an overpass.	67%
06	A dump truck collided with the central median of the road in front of the mine exit.	80%
07	A crane truck, in an inappropriate maneuver, collided with an ambulance.	100%
08	Due to the alleged distraction, a backhoe collided with a pole	90%
09	A fire occurred due to oil leakage during the maintenance of a slag ramp with a wheel loader. The operator had to go out the window.	63%
10	A rear-end collision occurred between two forklifts.	87%

An important result that highlights the predictive capacity of the system was that, when analyzing the 10 cases, we identified that in addition to the historical data, the evaluation of the Prontos System identified deviation in the test that preceded the accident in 100% of the cases - that is, in the last evaluation performed. Of these, 40% were significant alterations that generated actions to suspend or block the immediate activity. Therefore, the system effectively generated an opportunity to remove from risk. In these cases, the alterations occurred in the parameters of Attention, Impulse Control and/or Risk Predictor.

The time interval between the last readiness assessment and the respective accidents is also scored, ranging from 14 minutes apart to 13 days. In 90% of the cases, however, the break was longer than 5 hours – which reinforces the importance of intra-day assessments (also part of the system's method) in order to also investigate the effects of the workday and how they can impact an individual's readiness. In forty percent of the cases, in turn, there was an interval of more than one day.

4. DISCUSSION

In this series of ten occurrences of occupational accidents, two deaths are observed. It is noteworthy that in all cases the Readiness Assessment Program (FOCOS/Prontos System) identified alterations in the assessed parameters of all victims, both in the 30 assessments that preceded the occurrence, and in the last readiness assessment that preceded the accidents, generating restrictive actions for blocking/removing the risk in 40% of the cases just before the accident. In this sense, this tool has proven to be useful and sensitive in preventing accidents and deaths in Brazilian companies that present such high annual accident rates, where technology allows for quick decision making when faced with risk situations [28,29].

In this sense, the Prontos System has correctly identified in this and other studies the risk predictor variables in the prevention of accidents that include impulse control, reaction time, attention and concentration [30] - which does not mean that, in practice, the recommendations made by the system were rigidly followed by the organizations. This stems from numerous factors, of which we mention here some of the most common: a) non-withdrawal from risk by the immediate leadership, either by deliberation to the contrary or by omission; b) non-performance of the assessment by the user on the day of the accident itself, excluding the possibility of creating a barrier at that moment; c) flows and

rules parameterized by the client, since it determines how many and which deviations will justify the withdrawal from risk, and may be less or more rigid. Therefore, even with alterations and risk prediction, the action was not necessarily of removal from risk.

Organizations have already created action plans to mitigate the subjective effects of human interaction (such as leadership or others) in order to ensure the removal from risk. This includes the systemic integration of assessments with turnstiles for blocking or even ignition systems that prevent startup, guaranteeing that the system's action is fulfilled and the person is removed from the risk, preventing recurrence of cases. It is understood that the process of studying accidents is a powerful tool for prevention, as long as corrective actions are implemented, such as those mentioned above, which strengthen the effectiveness of the method. Studies already published and cited throughout this work, and others in progress and published a *posteriori* conducted by the CNPq research group "Science, Technology and Innovations in Mental Health and Quality of Life", show the substantial reduction of accidents after corrective actions in these companies.

A very important point that needs to be made is that there are, however, many other similar cases of repeated alterations in the assessment's results that were properly removed from risk after the recommendation of the Prontos System, ensuring non-exposure to risk. This is confirmed by studies conducted by the companies and that attest to the reduction in the Accident Frequency Rate after the implementation of Prontos [31], as well as, comparatively, by the higher incidence of accidents and incidents in populations not yet mapped for daily assessment – often due to the process being implemented in phases, with gradual expansions, or even due to mapping criteria that prioritize high criticality activities.

Once the employee presents, in the readiness assessment, repeated alterations in the same parameters – as happened among the ten cases studied – this may indicate a point of attention on prevention and creation of barriers to avoid the occurrence of accidents, which enables important learning for customers who, with these studies, can review their risk removal criteria, making them more restrictive.

The Prontos System also contributes to making the work environments more psychologically safe, by stimulating users to seek dialogue with their immediate supervisor and, at the same time, creating recommendations and actions for the leader aiming at dialogue with their team – thus creating the opportunity to reinforce the communication links, making active care feasible. With this, it is also believed that leaders will become more engaged in actions, making the necessary decisions and removing their employees from risk. It is also of paramount importance that organizations provide the conditions for leaders to be able to remove the risks, which can often create substitution needs for the sake of safety and life.

It is also noteworthy, in the results analyzed in this study, that of the 10 rare cases only 01 presented well-being complaints associated with alterations in Readiness. This reinforces the importance of not relying on subjective data (self-report) that can be influenced by psychological safety, but also by self-knowledge and company culture. It highlights, therefore, the need for computerized, objective methodologies, such as the FOCOS/Prontos System, in which results are independent of self-reporting and subjective factors.

In this sense, the prevention of health and safety at work acts on unsafe physical conditions and technical factors, in the prevention of unexpected events [18, 32]. But despite the technical issues, the causes related to the culture of unsafe human behavior, personality traits and impulsiveness must be addressed, which interfere in the dynamics of occupational accidents [5,9,33]. As an alternative, it is necessary to invest in actions to minimize mental fatigue in workers, intervening in the control of schedules, shifts and workloads, planned rest, climatization of the environment, considering that extreme temperatures imply serious occupational risks, job satisfaction by providing safe and comfortable spaces, promoting social interaction, requiring the use of personal protective equipment and enabling psychological counseling [10,11,14,16,17,34,35,36,37].

Finally, regarding the limited sample of 10 cases studied in this work, some factors influence the rarity of the cases, including a) the reduced frequency of accidents, especially in companies that use the FOCOS/Prontos System, b) the need to meet the requirements and complete information to be comparable to each other and c) the concern of large companies to openly provide information related to serious accidents, of a confidential nature. In scientific literature,

however, it is already considered important to analyze even a single case in the event of a rarity.

It is also emphasized that the relevance of this study lies in the early detection of risk patterns, aiming to reduce the costs associated with serious and fatal accidents, as well as the psychosocial impacts for the workers. Although computerized tools are available to identify predictive risk factors, occupational accidents are still a reality due to their multifactorial nature. Therefore, it is necessary to adopt approaches that integrate multiple data and consider the various conditions that influence accidents in order to increase the accuracy of the prediction.

The Computerized Readiness Assessment Test (FOCOS/Prontos System) was able to identify correlations between unsafe behaviors, emotional states, decreases in attention and other factors that can lead to accidents. However, despite these technologies, undesirable work-related events still occur, including physical injuries, deaths, and property damage. This highlights the importance of considering the multifactorial aspects in the lack of occupational safety, which involves not only human and behavioral factors, but also environmental, operational, and socio-occupational aspects.

This indicates the ongoing need to invest in knowledge, technologies and skills to address safety challenges in the workplace. Strategies that prioritize competence and knowledge improvement, the use of technological tools, checks and audits, and the establishment of appropriate barriers are key to preventing the occurrence of unexpected events. All ten cases reported here were studied individually in the companies in order to extract lessons learned, increasing the barriers and reinforcing the importance of immediate management – such as, for example, integrating the tool with turnstile and ignition systems for immediate blocking in case of changes in readiness.

5. CONCLUSION

This study presented a series of ten occupational accident cases reported by five companies using the Computerized Readiness Assessment Test (FOCOS/Prontos System) as a risk assessment tool. The analysis of the results indicated that the system was able to identify alterations in the readiness parameters of 100% of the workers involved in the cases analyzed, demonstrating its predictive capacity in identifying the risk of accidents, and high association with the parameters, with emphasis on the *risk predictor*, altered in 60% of the cases and which identifies that, in the history of assessments, the individual has had behavior similar to that of people who have already suffered work accidents.

In short, the study demonstrates the effectiveness of the Computerized Readiness Assessment Test in the identification of predictive variables of occupational accidents. It is acknowledgeable that the constant learning from the experiences and cases over the years produces rich knowledge on how to prevent accidents over time. Future studies with larger and more diverse samples will be conducted, which does not diminish the powerful outcome of the results presented here in the series of rare cases. The safety of workers must be a top priority for all organizations, in order to safeguard their health and well-being and avoid material and psychosocial harm.

CONSENT

It is not applicable.

ETHICAL APPROVAL

The study is in accordance with CNS Resolution 466/12 and was approved by CEP/EMESCAM under opinion number 2.432.995.

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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