

Original Article

Psychosocial Risks Assessment in Cryopreservation Laboratories

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ARTICLE INFO

Article history:

Received 5 March 2020

Received in revised form

29 June 2020

Accepted 7 July 2020

Available online 26 July 2020

Keywords:

Artificial neural networks

Cryopreservation laboratories

Health and safety management

Psychosocial risks

Risk assessment

ABSTRACT

Background: Psychosocial risks are increasingly a type of risk analyzed in organizations beyond chemical, physical, and biological risks. To this type of risk, a greater attention has been given following the update of ISO 9001: 2015, more precisely the requirement 7.1.4 for the process operation environment. The update of this normative reference was intended to approximate OHSAS 18001: 2007 reference updated in 2018 with the publication of ISO 45001. Thus, the organizations are increasingly committed to achieving and demonstrating good occupational health and safety performance.

Methods: The aim of this study was to characterize the psychosocial risks in a cryopreservation laboratory and to develop a predictive model for psychosocial risk management. The methodology followed to collect the information was the inquiry by questionnaire that was applied to a sample comprising 200 employees.

Results: The results show that most of the respondents are aware of the psychosocial risks, identifying interpersonal relationships and emotional feelings as the main factors that lead to this type of risks. Furthermore, terms such as lack of resources, working hours, lab equipment, stress, and precariousness show strong correlation with psychosocial risks. The model presented in this study, based on artificial neural networks, exhibited good performance in the prediction of the psychosocial risks.

Conclusion: This work presents the development of an intelligent system that allows identifying the weaknesses of the organization and contributing to the enhancement of the psychosocial risks management.

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1. Introduction

According to the Portuguese general Labor Law, the employers should identify the riskiness to which workers are exposed and perform the risk assessment. Thus, it is of utmost importance to understand this phenomenon in terms of occurrence, prevalence, and prevention in various professional activities [1]. Beyond the physical, chemical, and biological risks, due to the significant changes that have taken place in the working world, in recent years the psychosocial risks have emerged, with negative consequences for society, businesses, and workers [1–3]. Psychosocial risks derive from deficiencies in work design, organization, and management, as well as from a problematic

social working context and may have psychological, physical, and social effects such as work-related stress, burnout, or depression [3].

The study of this theme began to develop in 1950, when the psychological aspects of the work became an object of research. Attention to this phenomenon became more pronounced in 2000, after an increase in serious accidents at work was noted. However, psychosocial risks are still identified today as a major challenge for occupational health and safety professionals [3,4].

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2. State of art

2.1. Psychosocial risks

Psychosocial risks are a relatively recent concept and refer to conditions present in work situations, related to work organization, hierarchy, performance of the task, and the work environment, which may favor or impair work activity, as well as the quality of life, well-being, and health of workers [5]. These conditions, when favorable, foster the personal development of individuals. Conversely, when unfavorable, undermine the health and well-being, becoming a source of occupational stress with potential to cause psychological, physical, or social harm to individuals [4].

Psychosocial risks can be caused by a diversity of factors. Some may be intuitive, whereas others require detailed analysis to be identified as underlying causal factors. As a result, there are usually no quick fixes at hand, that is, a continuous and effective management process is required. To achieve this level, it is important to understand the most important underlying causal factors before selecting solutions [5]. The factors that may lead to psychosocial risks are related to content of the work, workload and work rate, working hours, control, environment and equipment, culture and organizational function, interpersonal relationships at work, organization role, development of career, and work–home interaction, as shown in Fig. 1A.

Content of the work refers to the lack of short work cycles, to the automatic or meaningless work, and to the under/over use of worker's skills (i.e., skills do not correspond to the tasks assigned). The lack of variety and complexity of tasks and the consequent monotony or repeatability can also be a source of suffering at work [4,6].

Workload and work rate is related to the inability to cope with the demands of the profession (e.g., when the worker feels that the demands of the job are excessive and cannot cope with them or the lack of sufficient requirements). This item is also associated to high levels of emotional pressure and mental burden, as well as the continued existence of difficult deadlines [6].

Working hours is related to working hours (e.g., shift work, night shifts, Sunday work, rigid and inflexible work hours, unpredictable hours, and long hours or those that do not allow socialization). These issues are seen as being inconsistent with the preservation of the well-being and influence temporal and emotional availability for personal and family relationships [6].

Control refers to the person's stress level that can be influenced by the person's level of control over workload and work rate, as

well as other risk factors [6]. When a worker has control and influence over how his work is planned and carries out, it helps him cope with challenges ahead. Conversely, if the worker does not have the expected control, whether other people determine the pace or the way of work, the worker can feel stress. Lack of flexibility, as well as low participation in decision-making, contribute to stress and prevent a person from developing and using new skills [6].

Environment and equipment refers to inadequate availability, adequacy, or maintenance of equipment as well as precariousness and job insecurity. This item also stresses the poor environmental conditions, such as lack of space, poor lighting, excessive noise, or high temperatures, which may hinder workers' ability to concentrate [6].

Culture and organizational function relates to the levels of support and encouragement for problem-solving and personal development [6]. Positive support and feedback (from colleagues, from leaders, social support, or direct support for the profession) can help people overcome difficulties and lead to job satisfaction. This item is also related to communication, definition of organizational objectives, structural variables, hierarchical structure, leadership style, recognition at work, employees' freedom of expression, and changes within organization [4].

Interpersonal relationships at work are related to differences of opinion in a work environment. Work relationships can cause stress when people suffer discrimination, have poor relationships with superiors, colleagues, face interpersonal conflict, or lack social support [6]. In addition, inadequate, incomprehensible, or unbearable supervision should be included in this item. Another factor that cannot be overlooked and causes stress is bullying/mobbing [5]. Bullying may involve violence (physical, verbal, or psychological), intimidation, sexual harassment, and subtler acts such as physical or social isolation, excessive supervision, unfounded criticism, the impoverishment of tasks, evasion of information, or persecution at work [4].

Organization role refers to stress that arises from the lack of clarity about the roles and responsibilities that people have or when the roles and responsibilities give rise to conflict with colleagues, superiors, or customers. This factor also covers the stress that arises from the feeling that his role is incompatible with his skills and abilities [6].

Career development refers to the stress due to career stagnation, under-promotion, over-promotion, low compensation, or low commission. Career development also encompasses issues linked

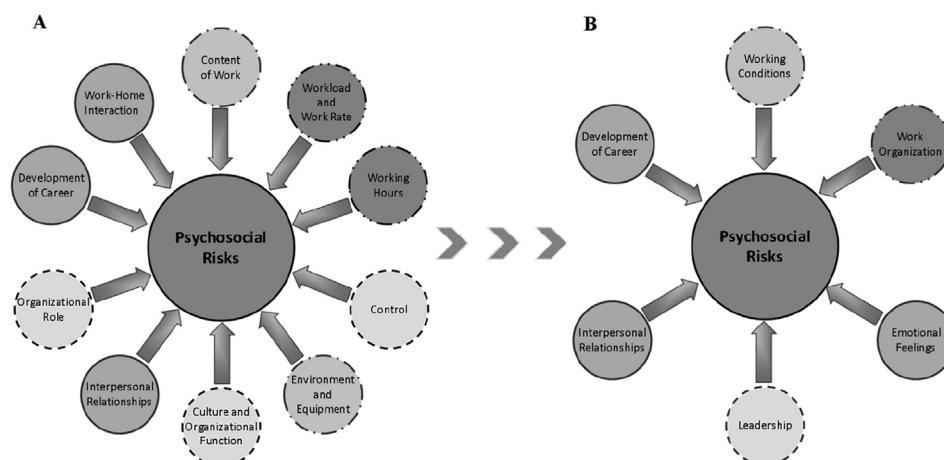


Fig. 1. (A) Psychosocial risks factors. (B) Categories of psychosocial risks factors.

to job insecurity, career uncertainty, and low social value to work [4].

Work–home interaction is related with the conflict between work and family demands which can lead to conflicts of time, commitment, and support. In addition, it encompasses the stress that arises because of low home support and from dual-career problems [6].

Some of aforementioned factors can be grouped into generic categories, namely *Work Conditions*, *Work Organization*, and *Leadership*. The former one includes the factors Environment and Equipment and Content of Work, whereas the second comprises Workload and Work Rate and Working Hours. Finally, the third category groups the factors Culture and Organizational Function, Control and Organizational Role (Fig. 1B).

Recent studies show that psychosocial risk analysis in organizations is increasingly common in the industrial sector [7–9] and less frequent in the laboratory sector. Ferguson et al. [7] studied the psychosocial and biomechanical factors in furniture distribution workers, involving 454 participants at nine furniture distribution facilities during 6 months. The authors developed a multivariate logistic regression model that includes baseline functional performance probability, facility, perceived workload, inter-mediated reach distance number of exertions above threshold limit values, job tenure manual material handling, and age combined. The model sensitivity and specificity was of 68.5% and 71.9%, respectively.

Joensuu et al. [8] examined associations between job control, social support, and mental ill health in a multinational forest industry corporation. The 13,868 employees of a Finnish forest company with no previous hospital admissions for mental disorders responded to questionnaires on decision authority, skill discretion, coworker, and supervisor support [8]. The results show that high skill discretion was related with reduced risks of hospital admission for mental disorders, whereas high decision authority was connected with an elevated risk. Furthermore, the authors concluded that high decision authority was a risk factor for alcohol-related and depressive disorders, whereas good coworker support was linked with a reduced risk of nondepressive nonalcohol-related mental disorders. Supervisor support, in turns, was not associated with any mental disorders [8].

Metzler et al. [9] compared different methods for evaluating psychosocial hazards in the scope of risk assessment in a sample of 549 blast furnace workers of a German steel manufacturing. The authors highlighted that the risk management was strongly influenced by the choice of risk evaluation method because the measures to minimize the risks are directed only to the ones identified and in accordance with their level of priority.

In analysis laboratories, regardless of the sector of activity, the excessive pace of work, monotony, routine, as well as problems of interpersonal relationships, are examples of psychological risks for the workers. Bronkhorst [10] realized a hierarchical linear modeling of physical safety behavior to examine the relationship between job demands, job resources, safety climate, and safety behavior among employees working in health care. The author used a sample of 6230 health-care employees of 52 different Dutch organizations. Regardless of the focus (i.e., physical or psychological safety), this study shows that the consolidation of the safety climate increases employees' safety behavior. In addition, the authors point out that the organization's safety climate is an ideal target of intervention to avert and enhance negative physical and psychological health and safety outcomes, mainly in times of doubt and change.

Aiming to estimate the association between psychosocial risk factors in the workplace and musculoskeletal disorders in nurses and aides Bernal et al. [11] examined 17 papers. Despite the low

heterogeneity of cohorts, the authors identified associations between high psychosocial demands and low job control with prevalent and incident low back pain, prevalent shoulder pain, prevalent knee pain, and prevalent pain at any anatomical site.

All these studies show the main role of the psychosocial risk in organizations to minimize possible damage to the health of employees. In addition, the foregoing demonstrates the relevance of the development of models aiming to predict the level of psychosocial risks based on employees' experiences. In the present work, a predictive model based on artificial neural networks (ANNs) will be presented.

2.2. Artificial neural networks

ANNs are computational tools that aim to simulate the human brain and nervous system. The multilayer perceptron is one of the utmost common ANN architectures, in which neurons are assembled in layers and only forward connections exist [12]. ANNs are increasingly applied in data mining because of their good performance in prediction [13]. In last decades, several studies have been published showing the usefulness of ANNs to apprehend complex relationships between variables, in various areas of application (e.g., environment [14,15], health [16,17], and law [18–20] just to name a few.

3. Methods

3.1. Place of study

This study took place in a cryopreservation laboratory located in the north of Portugal. In Portugal, the quality and safety requirements for human tissues and cells are set by the Portuguese Ministry of Health [21]. However, the criteria implemented by the laboratory under study are even stricter. The laboratory participates in external quality assays, where national and international entities test and certify the reliability of the stored sample quality control tests. Furthermore, the laboratory has the accreditation of the American Association of Blood Banks, which sets the most stringent quality criteria in the industry worldwide [22]. The cryopreservation laboratories were chosen because the work performed in them requires immediate results, confidentiality, and secrecy and deals with large volumes of information. The pressure associated to these requirements can create conditions for the appearance of psychosocial risks in the workers, and it is important to study these risks.

3.2. Participants

This study included 200 participants aged between 17 and 80 years, with an average of 41 ± 23 years old. The gender distribution was 44.5% and 55.5% for male and female participants, respectively. The participants belong to different departmental areas in the laboratory (i.e., quality management, human resources, finance, administrative, commercial, and technical).

3.3. Data collection

Aiming to perform the purposes defined before, a versatile tool to data collection was used. After taking into consideration, the advantages and limitations intrinsic to possible techniques, the inquiry by the questionnaire was chosen because it has a well-defined structure and enables the conversion of the qualitative information into a quantitative [23–25].

A questionnaire aiming to evaluate the perception of psychosocial risks in the workplace was designed specifically for this study and applied to a cohort of 200 employees. The questionnaire was

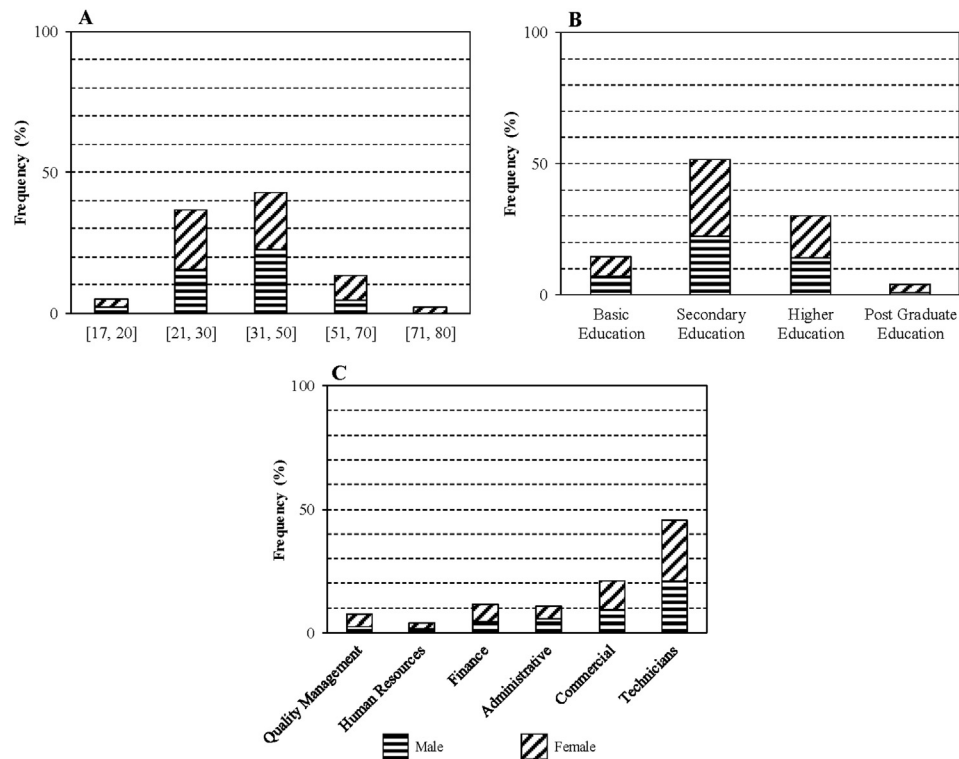


Fig. 2. (A) Sample characterization in terms of age groups. (B) Sample characterization in terms of academic qualifications. (C) Sample characterization in terms of departmental areas.

organized into three sections, where the former one includes the general questions related with workers' age, gender, academic qualifications, and departmental areas. The second one comprises statements related with the work conditions, organization, leadership, career development, interpersonal relationships, and emotional feelings. Finally, the third section comprises issues related with the workers' opinions about the psychosocial risks. In the first part of the questionnaire the answers are descriptive, whereas in the second one the Likert scale with four levels (*strongly disagree*, *disagree*, *agree*, and *strongly agree*) was used. In the third section, the respondents choose five terms (the ones that they consider more relevant) from a list of 12 terms, ranking them in accordance with their relevance, using a numeric scale that varies from 1 to 5 (Annex 1).

The validation of the questionnaire follows practices of Bell [26]. Thus, the questionnaire was evaluated by a group of experts (i.e., a group of auditors) that suggested some corrections. After expert analysis, the questionnaire was modified and applied to a restrict group of employees, not included in the sample, to assess its validity and to identify difficulties in the interpretation of the questionnaire. The updated version was applied individually to the entire sample, in person, by the researcher. The return rate was 90.9% (200 inquiries received in 220 delivered).

3.4. Qualitative data processing

Aiming the conversion of qualitative information into quantitative information followed the method proposed by Fernandes et al. [27]. As per this method, a set of n issues regarding a particular subject is itemized into a unitary area circle split into n slices, where the marks in the axis correspond to each one of the possible answers, as described in the section 4.3.

3.5. Artificial neural networks

The software used to implement ANNs was the Waikato Environment for Knowledge Analysis, keeping the default software parameters [28,29]. Aiming to guarantee statistical significance of the results, 30 experiments were applied in all tests. In each simulation, the database was randomly split into two mutually exclusive partitions, i.e., the training set, with 2/3 of the data, used to build up the model, and the test set, with the remaining examples to evaluate its performance [30].

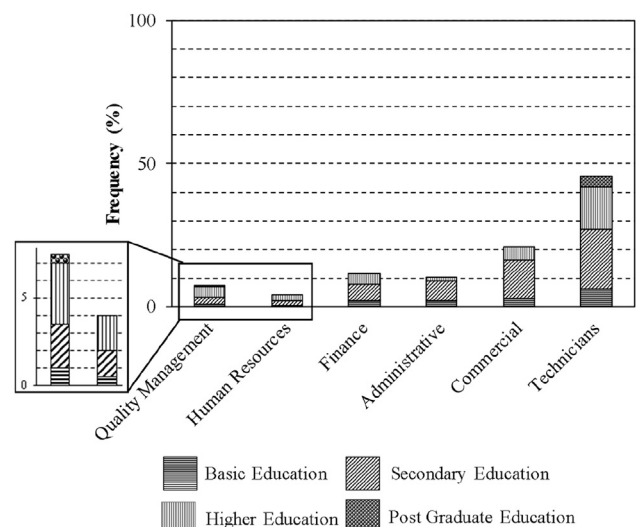


Fig. 3. Distribution of academic qualifications of the respondents by department.

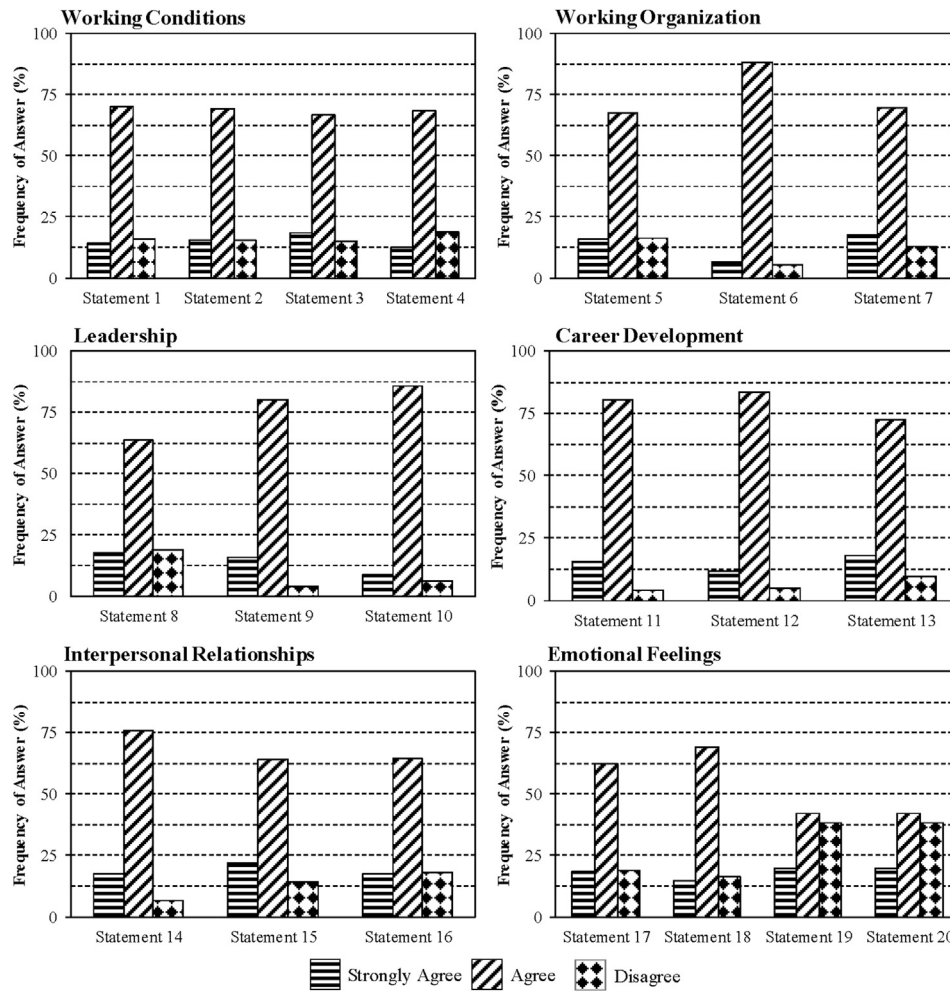


Fig. 4. Respondents' agreement/disagreement with the statements regarding each factor.

3.6. Ethical aspects of the study

The respondents took notice of the goals of the study participated voluntarily, without any pressure or coercion, and were informed that their grades would not be affected. The participants gave an informed consent to participate in the study. The study was conducted in compliance with the relevant laws and institutional guidelines and was approved by the relevant authorities.

4. Results and discussion

4.1. Sample characterization

Respondents were organized into age groups (i.e., 17–20, 21–30, 31–50, 51–70, and higher than 70 years old). 79.5% of participants are aged between 21 and 50 years. In all age groups, the percentage of female participants is higher, except in the group 31–50 where 22.5% of respondents are male and 20.5% are female (Fig. 2A). Regarding academic qualification, 14.5% of the cohort stated to have basic education, 51.5% declared to finish secondary education, 30.0% affirmed to have a degree, and 4.0% declared to have post graduate education (Fig. 2B). Fig. 2B also shows that the distribution of respondents by gender is very similar for the different types

of academic qualifications. Concerning departmental areas to which respondents belong, 7.5% are allocated to the quality management department, 4.0% to the human resources department, 11.5% to the finance department, 10.5% to the administrative department, 21.0% to the commercial department, and 45.5% to the technical department (Fig. 2C). Fig. 2C also shows that in all the departments the percentage of female respondents is higher, except in the administrative department where 5.5% of respondents are male and 5.0%, female.

To characterize the laboratory, the graph shown in Fig. 3 presents the distribution of the academic qualifications of the respondents by department. A perusal of Fig. 3 reveals that only in quality management and human resources departments the percentage of respondents that claim to have higher education are greater than the percentage of respondents that declare to have basic/secondary education. The remaining departments show an inverse trend, being the administrative, commercial, and technical departments those that present differences higher than 7.5% between respondents with basic/secondary and higher education.

4.2. Answer frequency analysis

Fig. 4 presents the results obtained in the second part of the questionnaire, where respondents expressed their opinion on the

Table 1
Correspondence between the statements included in the questionnaire and the psychosocial risk factors

Factor	Working conditions	Work organization	Leadership	Career development	Interpersonal relationships	Emotional feelings
Statements	S1 – S4	S5 – S7	S8 – S10	S11 – S13	S14 – S16	S17 – S20

sets of statements regarding each of the psychosocial risk factors. The graphs show the frequency of answering to each factor statement (Table 1).

Regarding *Working Conditions*, the analysis of results shows that a percentage of respondents ranging between 66.5% and 70% consider they have good working conditions (S1), resources and equipment adequate to perform the work (S2). Furthermore, they consider that the work is not monotonous and routine (S3) and need learning and ongoing updates (S4). However, a percentage ranging from 15% to 19% has an opposite opinion, which may point out a need for improvement. With regard to *Work Organization*, the overwhelming majority of respondents consider that decision making and goal setting take into account the workers' opinions (S6). Taking a glance to the answers related to goal setting (S5) and the service distribution (S7) shows that the majority of the participants declare they are clear and evenly, respectively. However, a percentage of about 10% disagree, which may suggest that leaders should pay attention to these points. The results related to *Leadership* show that most respondents claim that their work is recognized (S10) and has a favorable opinion about leadership (S9). Nevertheless, 19% state that the guidelines and priorities are unclear (S8), being an issue that should be improved. Concerning *Career Development*, the overwhelming majority of participants have a very positive opinion. Only a percentage less than 10% is dissatisfied with the expectations of career development. The graphs related with *Interpersonal Relationships* (S14 to S16) show that more than 80% of respondents consider that there is a good

relationship between colleagues. However, 14% and 18% of respondents have a negative opinion regarding communication/information sharing (S15) and mutual help/support (S16), respectively. These relatively high values of unfavorable opinions indicate that this is a point where improvements are needed. Finally, with regard to *Emotional Feelings* (S17 to S20), most participants have a favorable opinion, which ranges between 61.5%

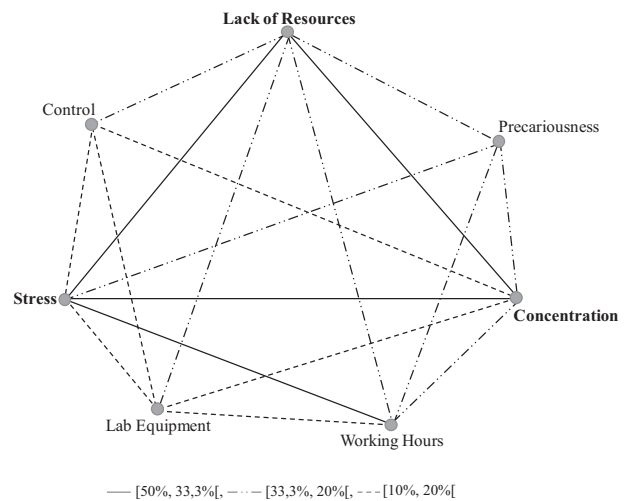


Fig. 6. Binary associations between terms selected by more than 30% of respondents. (Bold stands for terms of first group, and no bold denotes terms of second group).

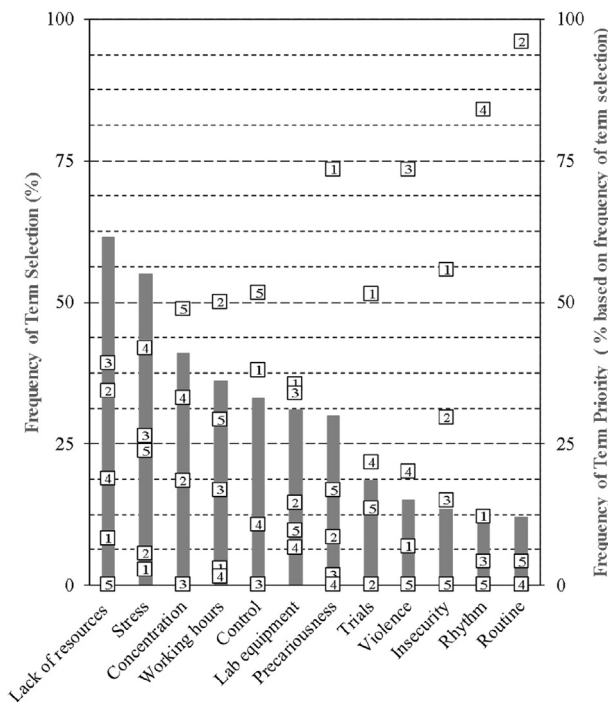


Fig. 5. Frequency of term selection versus term priority (considering only the respondents that choose the term).

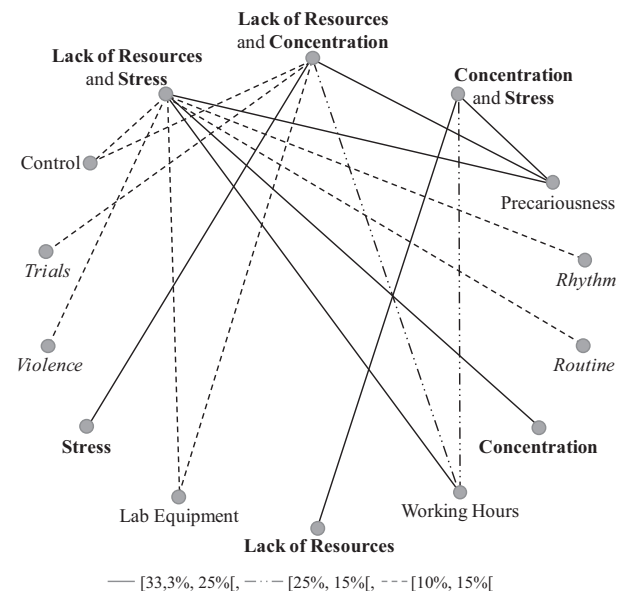


Fig. 7. Ternary associations between terms. (Bold stands for terms of first group, no bold denotes terms of second group, and italics indicate terms of third group).

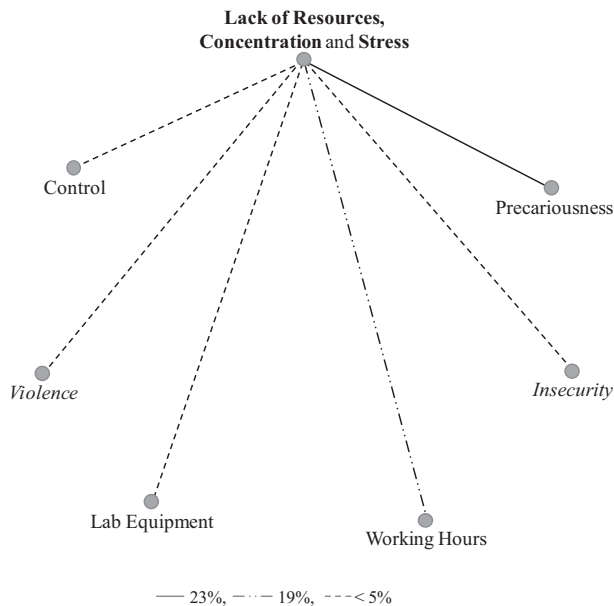


Fig. 8. Quaternary associations between terms. (Bold stands for terms of first group, no bold denotes terms of second group, and italics indicate terms of third group).

(S19, S20) and 83.5% (S18). In fact, the statements related with professional life/personal life overlapping (S19) and time available/tasks to perform (S20) collected the highest number of negative responses.

The statements included in the questionnaire were elaborated so that a higher percentage of positive answers correspond to a lower psychosocial risk. Thus, the overall analysis of the results shown in Fig. 4 suggests that the factors *Interpersonal Relationships* and *Emotional Feelings* are the ones that more contribute to psychosocial risk in the organization under study. Conversely, *Leadership* and *Career Development* seem to have a minor contribution.

These results are in agreement with those obtained by Ando et al. [31] and MacDonald et al. [32]. The authors refer that a strong association between psychosocial risk factors in the workplace and musculoskeletal disorders exists, identifying the working conditions (e.g., monotony, routine and repetitive movements) as the main cause.

Fig. 5 presents the results obtained in the third part of the questionnaire, where respondents select and classify, based on their opinion, the five more relevant terms related with psychosocial risks. The frequency of term selection is presented in the bar chart and may be read on the left side scales. The frequency of term priority (scale on the right side) was computed considering only the respondents that chose that term. The analysis of the frequencies of term selection allows identifying three groups. The first one includes the terms *Lack of Resources*, *Stress*, and *Concentration* that were selected by more than 40% of respondents. The second group comprises the terms *Working Hours*, *Control*, *Lab Equipment*, and *Precariousness* that were chosen by 30% to 36% of respondents. Finally, the third group is formed by the terms *Trials*, *Violence*, *Insecurity*, *Rhythm*, and *Routine*, chosen by less than 20% of respondents.

Regarding the priority given to the selected terms, only a small percentage of participants who chose terms of group 1, classified them as the first priority (ranging from 0% to 8%) or as the second priority (varying between 5.4% and 34.1%). *Lack of Resources*, *Stress*, and *Concentration* were mainly chosen as the third, fourth, and fifth priority, respectively (Fig. 5). Despite the fact that they

were selected by more than 40% of respondents, the terms of group 1 are not considered as the ones that best describe psychosocial risks. As regards to the terms of the second group, it should be emphasized that *Precariousness*, *Control*, and *Lab Equipment* were classified as the first priority by, respectively, 73.3%, 37.9%, and 35.5% of the participants who selected them. Furthermore, it should be highlight that *Working Hours* was classified as the second priority by 50% of the respondents who selected it. Finally, in the third group there was a similar trend. *Insecurity* and *Trials* were classified as the first priority, respectively, by 55.6% and 51.3% of the participants who selected them, whereas *Routine* was classified as the second priority by 95.8%. These results suggest that the terms of second and third groups, although chosen by a smaller number of respondents, were considered by them as the best to describe the psychosocial risks.

The graph presented in Fig. 6 shows the relative frequency of binary associations between terms selected by more than 30% of participants. Their analysis shows that any possible combination of terms of group 1 (*Lack of Resources*, *Stress*, and *Concentration*) was chosen by at least 33% of participants. Regarding associations between terms of group 1 and group 2, only the combination between *Stress* and *Working Hours* was selected by more than 33% of participants. The associations *Stress* and *Precariousness*, *Concentration* and *Precariousness*, *Concentration* and *Working Hours* and all possible combinations between *Lack of Resources* and terms of group 2 (*Working Hours*, *Control*, *Lab Equipment* and *Precariousness*) were chosen by a percentage of participants ranging between 20% and 33.3%. The remaining binary associations were selected by less than 20% of participants.

The frequency of association between sets of three terms was also studied (Fig. 7). It was found that the terms of the group 1 were simultaneously selected by a percentage of participants ranging between 20% and 33%, as well as all ternary associations between *Precariousness* and terms of first group. Sets of three terms containing *Working Hours* and terms of first group were selected by at least 15% of respondents. To finish the analysis of Fig. 7, it also noted that a percentage between 10% and 15% of respondents set associations between *Rhythm*, *Lack of Resources* and *Stress*; *Routine*, *Lack of Resources* and *Stress*; and *Trials*, *Lack of Resources* and *Concentration*.

The graph depicted in Fig. 8 shows the frequency of quaternary associations between terms selected by the participants. Its analysis shows that *Lack of Resources*, *Concentration*, and *Stress* were chosen simultaneously with *Precariousness* by 23% of participants and with *Working Hours* by 19%. Quaternary associations between terms of group 1 and the remaining terms of group 2, i.e., *Control* and *Lab Equipment*, exhibit frequencies less than 5%. Regarding terms of third group, only *Violence* and *Insecurity* were selected together with the terms of group 1.

In addition, this analysis enables to identify, among the less selected factors, the ones that present a strong association with the most chosen by the respondents. A perusal to Figs. 5 and 8 reveals that *Precariousness* (selected by only 30% of respondents) was associated in 23% of cases with the terms of group 1, being ticked as first priority by 73.3% of those who chose it. A similar result was obtained for *Working Hours*, selected by 36% of respondents, but linked in 19% of cases to the terms of group 1, being ticked as second priority by 50% of those who chose it.

4.3. Psychosocial risk assessment

Aiming to gather information about psychosocial risk factors, the second section of the questionnaire comprises statements related to work conditions, organization, leadership, career development, interpersonal relationships, and emotional feelings.

PSYCHOSOCIAL RISKS SURVEY

PART II

For each statement tick the option that best reflects your opinion.

Working Conditions				
	Strongly Agree	Agree	Disagree	Strongly Disagree
S1. There are good working conditions.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S2. There are resources and equipment needed to perform the work.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S3. The work done isn't monotonous and routine.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
S4. Work requires learning and ongoing updates.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Work Organization				
	Strongly Agree	Agree	Disagree	Strongly Disagree
S5. There is a clear definition of objectives.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S6. There is involvement in decision making and goal setting.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S7. The service is distributed evenly.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Leadership				
	Strongly Agree	Agree	Disagree	Strongly Disagree
S8. The leader gives clear guidelines and sets priorities for the team.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
S9. The leader knows when to support and advise or give autonomy.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S10. The leader recognizes your work.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Career Development				
	Strongly Agree	Agree	Disagree	Strongly Disagree
S11. Employees aren't professionally stagnant.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S12. Prospects for career progression are good.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S13. The training and knowledge gained are valued for career progression.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Interpersonal Relationships				
	Strongly Agree	Agree	Disagree	Strongly Disagree
S14. There is a good relationship with your colleagues.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S15. There is good communication and sharing of information between colleagues.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
S16. The help and support of the colleagues are frequent.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Emotional Feelings				
	Strongly Agree	Agree	Disagree	Strongly Disagree
S17. The situations of verbal violence aren't recurrent.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
S18. There is flexibility and understanding for family life.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
S19. Work sometimes overlaps with social and family life.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
S20. The time you have is enough to accomplish your tasks.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Fig. 9. The answers of respondent #1 to the second part of the questionnaire.

Fig. 9 shows the answers of respondent #1 to the second part of the questionnaire.

To quantify the qualitative information presented in Fig. 9, the method proposed by Fernandes et al. [27] was followed. For each dimension (i.e., work conditions, organization, leadership, career development, interpersonal relationships, and emotional feelings) the correspondent answers were itemized into a unitary area circle. The marks in the axis correspond to the possible answer, i.e., *strongly agree*, *agree*, *disagree*, and *strongly disagree*. Taking as an example the

dimension *work conditions*, the answer of respondent #1 to statement 1 (S1) was *strongly agree*, and the correspondent area is computed as $\frac{1}{4} \times \pi \times \left(\frac{1}{\sqrt{\pi}}\right)^2 = 0.25$; the answer to the statement 2 (S2) was the alternative *agree* and the area is $\frac{1}{4} \times \pi \times \left(\frac{3}{4} \times \frac{1}{\sqrt{\pi}}\right)^2 = 0.14$. Finally, for the statements 3 and 4 (S3 and S4), the answers were *disagree* and the areas are $\frac{1}{4} \times \pi \times \left(\frac{2}{4} \times \frac{1}{\sqrt{\pi}}\right)^2 = 0.06$. The total

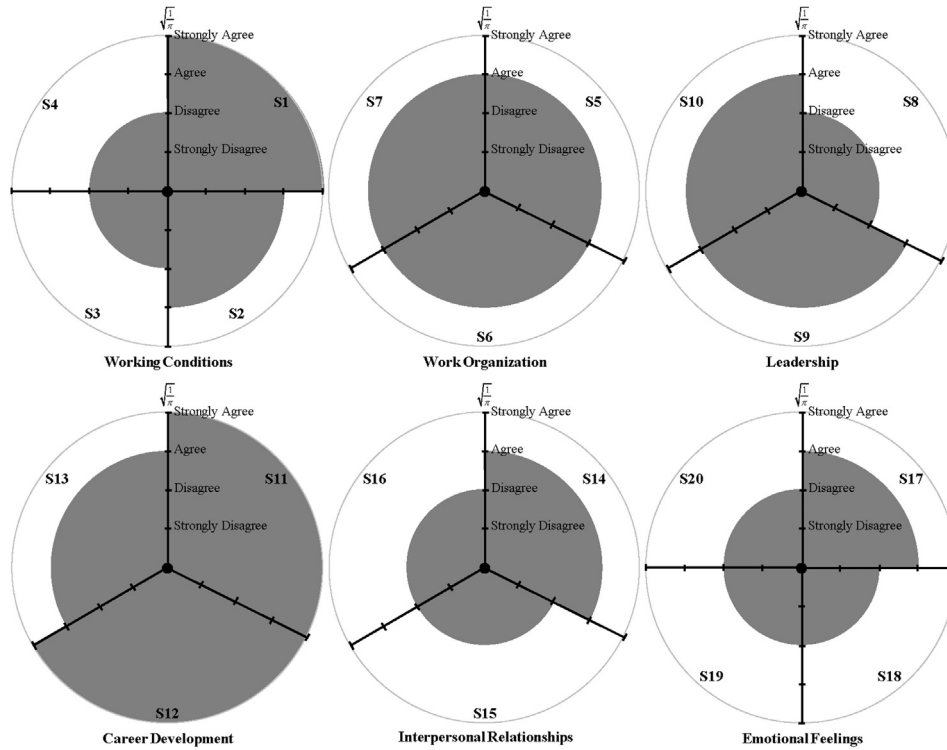


Fig. 10. A view of the qualitative data processing.

Table 2

A fragment of the knowledge base for psychosocial risk assessment

Respondent	Working conditions	Work organization	Leadership	Career development	Interpersonal relationships	Emotional feelings
1	0.51	0.57	0.46	0.85	0.35	0.19
2	0.67	0.71	0.35	0.57	0.46	0.40
...
200	0.70	0.60	0.85	0.71	0.57	0.48

Table 3

Confusion matrix regarding the ANN model for psychosocial risk assessment

Target	Predictive					
	Training set			Test set		
	Low	Medium	High	Low	Medium	High
Low	15	2	1	4	1	0
Medium	1	98	4	0	48	5
High	0	1	14	0	0	6

area (i.e., 0.51) is the sum of the partial ones, being the quantitative value regarding the dimension *work conditions* for respondent #1 (Fig. 10). For the remaining dimensions, the procedure is similar, and the results are shown in Table 2.

The performance of the ANN model can be assessed through the confusion matrix. Table 3 presents the confusion matrix for the ANN model shown in Fig. 11 (The values indicate the average of the 30 experiments). The values presented in Table 3 allow computing the model accuracy for training set (93.4%, i.e., 127 well

classified in 136) and for test set (90.6%, i.e., 58 well classified in 64).

To compute the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the model, the confusion matrixes regarding each possible output were conceived (Table 4). Sensitivity evaluates the proportion of positives cases (i.e., *Low*, *Medium*, or *High*) that are correctly identified as such, whereas specificity translates the proportion of negative ones that are correctly identified (i.e., *No-Low*, *No-Medium*, or *No-High*). PPV stands for the proportion of *Low*, *Medium*, or *High* cases well classified, whereas NPV denotes the proportion of *No-Low*, *No-Medium*, or *No-High* cases well labeled [33,34]. Table 5 presents the values obtained for those metrics. Sensitivity and specificity exhibit high values, from 0.80 to 0.99, indicating that the model exhibits a good performance in the evaluation of psychosocial risks. Regarding PPV and NPV metrics, the values computed range between 0.94 and 0.99, except for $PPV_{output-High}$ and $NPV_{output-Medium}$ (0.74, 0.54 and 0.86, 0.67, respectively, for training and test). Those results show that the confidence that can be placed when the model classifies a case as *High* or *No-Medium* is lower. Despite those weaknesses, the overall performance of the model is not affected. In fact, the model should

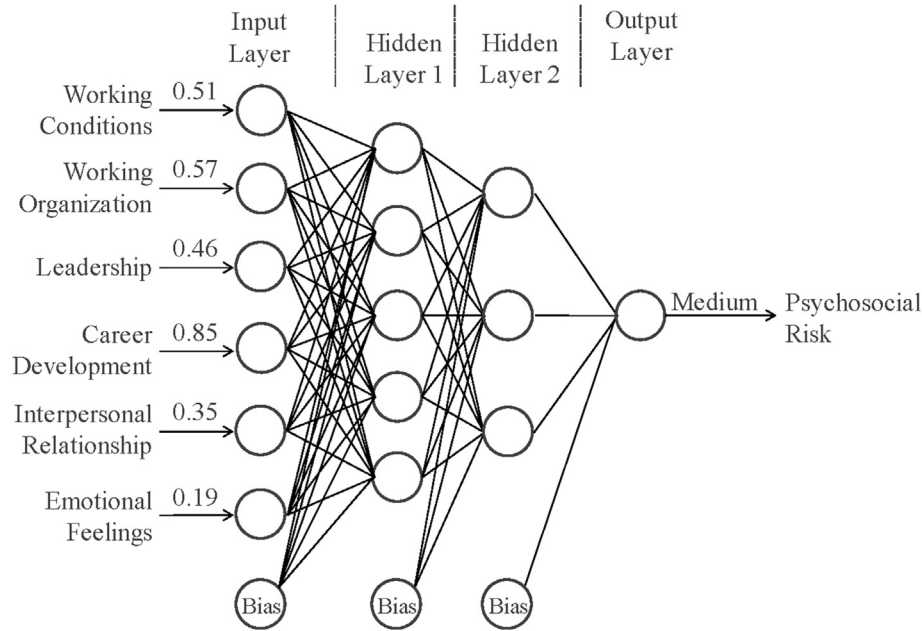


Fig. 11. ANN model for psychosocial risk assessment.

Table 4

Confusion matrix regarding each output classes of the ANN model for psychosocial risk assessment

Target	Predictive				Target	Predictive				Target	Predictive			
	Training set		Test set			Training set		Test set			Training set		Test set	
	Low	No-low	Low	No-low		Medium	No-medium	Medium	No-medium		High	No-high	High	No-high
Low	15	3	4	1	Medium	98	5	48	5	High	14	1	6	0
No-Low	1	117	0	59	No-Medium	3	30	1	10	No-High	5	116	5	53

Table 5

Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for each output classes of the ANN model, split by training and test

Output	Training set				Test set			
	Sensitivity	Specificity	PPV	NPV	Sensitivity	Specificity	PPV	NPV
Low	0.83	0.99	0.94	0.97	0.80	1	1	0.98
Medium	0.95	0.90	0.97	0.86	0.91	0.91	0.98	0.67
High	0.93	0.96	0.74	0.99	1	0.91	0.54	1

avoid classifying the *High* cases as *Low* or *Medium*, to identify all the problematic cases, i.e., workers at high psychosocial risk.

5. Study limitations

The results obtained in this study were very interesting. However, it is important to mention some limitations that prevented a more detailed assessment of the psychosocial risks to which workers in this type of laboratory are exposed. The main limitation is related to the sample size. The reduced number of workers in some departmental areas did not allow a more detailed analysis (i.e., department by department) of the psychosocial risks associated with the performance of different tasks with workloads differentiated. With a larger sample, it would also be possible to study the influence of other variables such as age, gender, or academic qualifications.

The questionnaire used to collect the data was conceived to be general, i.e., to be applied to all employees, regardless of the sector of the laboratory to which they belong. However, with a larger sample, differentiated data collection tools could be designed specifically for each departmental area.

6. Conclusions

Nowadays, psychosocial risk assessment has been left to the discretion of each organization. However, the standards used (i.e., OHSAS 18001 and ISO 9001) are not clear as to how these risks should be measured. The certifications based on these standards do not guarantee that psychosocial risks are, in fact, controlled. This study showed that *Interpersonal Relationships* and *Emotional Feelings* are the factors that more contribute to psychosocial risks, particularly the issues related with the overlapping of working and

personal lives, the lack of time to accomplish some tasks, the sharing of information, and peer support. This study also revealed that the concept of psychosocial risks is generally present among most respondents. Despite respondents having ticked the terms *Lack of Resources*, *Stress*, and *Concentration* as the ones that better describe the psychosocial risks, the terms *Precariousness*, *Control*, and *Lab Equipment* were the ones most often marked as first priority. Moreover, the terms *Lack of Resources*, *Working Hours*, and *Lab Equipment* were chosen simultaneously by a great number of respondents, as well as the terms *Stress*, *Working Hours*, and *Precariousness*. In addition, this work presents an intelligent decision support system that stands for a new approach to this problem using the ANN paradigm to assess psychosocial risks. The presented approach presents a worthy performance exhibiting sensitivities and specificities higher than 80%. This approach focuses on the processing of information, collected through inquiry by questionnaire, and aims to prevent recurrent events and to enhance the psychosocial risks management. Beyond the possibility of identifying the weakness of the organization, this system allows to concept and to design future improvement actions to promote the employees' quality of life. The results of this study cannot be generalized to all organizations because the employees are exposed to different risks depending on the sector and the type of activity in which they operate. However, these kinds of models can be used in any organization. For this, it is necessary to carry out an assessment of the risks to which employees are exposed and adjust the data collection tools (i.e., questionnaires).

Conflicts of interest

All authors have no conflicts of interest to declare.

Acknowledgments

This work has been supported by FCT – Fundação para a Ciência e Tecnologia within the R&D Units Project Scope UIDB/00319/2020 and UIDB/50006/2020.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.shaw.2020.07.003>.

References

- [1] EU-OSHA. Management of psychosocial risks at work: an analysis of findings of the European survey of enterprises on new and emerging risks. Luxembourg City: Publications Office of the European Union. 2012. Available from: <https://osha.europa.eu/en/publications/management-psychosocial-risks-work-analysis-findings-european-survey-enterprises-new/view>.
- [2] EU-OSHA. Expert forecast on emerging psychosocial risks related to occupational safety and health. Luxembourg City: Office for Official Publications of the European Communities. 2007. Available from: <https://osha.europa.eu/en/publications/report-expert-forecast-emerging-psychosocial-risks-related-occupational-safety-and>.
- [3] Leka S, Jain A. Health impact of psychosocial hazards at work: an overview. Geneva: World Health Organization. 2010. Available from: https://apps.who.int/iris/bitstream/handle/10665/44428/9789241500272_eng.pdf.
- [4] Lerouge L. Psychosocial risks in labour and social security law: a comparative legal overview from europe. Cham: North America, Australia and Japan. Springer; 2017.
- [5] Dollard M, Dormann C, Idris M. Psychosocial safety climate: a new work stress theory. Cham: Springer; 2019.
- [6] Eurofound., EU-OSHA. Psychosocial risks in europe: prevalence and strategies for prevention – a joint report from the European foundation for the improvement of living and working conditions and the European agency for safety and health at work. Luxembourg City: Publications Office of the European Union; 2014. Available from: <https://osha.europa.eu/en/publications/reports/psychosocial-risks-eu-prevalence-strategies-prevention/view>.
- [7] Fergunson S, Allread W, Burr D, Heaney C, Marras W. Biomechanical, psychosocial and individual risk factors predicting low back functional impairment among furniture distribution. Clin Biomech 2012;27:117–23. <https://doi.org/10.1016/j.clinbiomech.2011.09.002>.
- [8] Joensuu M, Väänänen A, Koskinen A, Kivimäki M, Virtanen M, Vahtera J. Psychosocial work environment and hospital admissions due to mental disorders: a 15-year prospective study of industrial employees. J Affect Disord 2010;124:118–25. <https://doi.org/10.1016/j.jad.2009.10.025>.
- [9] Metzler Y, Groeling-Müller G, Bellingrath S. Better safe than sorry: methods for risk assessment of psychosocial hazards. Saf Sci 2019;114:122–39. <https://doi.org/10.1016/j.ssci.2019.01.003>.
- [10] Bronkhorst B. Behaving safely under pressure: the effects of job demands, resources, and safety climate on employee physical and psychosocial safety behavior. J Saf Res. 2015;55:63–72. <https://doi.org/10.1016/j.jsr.2015.09.002>.
- [11] Bernal D, Campos-Serna J, Tobias A, Vargas-Prada S, Benavides F, Serra C. Work-related psychosocial risk factors and musculoskeletal disorders in hospital nurses and nursing aides: a systematic review and meta-analysis. Int J Nurs Stud 2015;52:635–48. <https://doi.org/10.1016/j.ijnurstu.2014.11.003>.
- [12] Haykin S. Neural networks and learning machines. 3rd ed. New York: Prentice Hall; 2009.
- [13] Mitra S, Pal S, Mitra P. Data mining in soft computing framework: a survey. IEEE Trans Neural Netw 2002;13:3–14. <https://doi.org/10.1109/72.977258>.
- [14] Allawi MF, Jaafar O, Hamzah FM, Abdullah SM, El-shafie A. Environ Sci Pollut Res 2018;25:13446–69. <https://doi.org/10.1007/s11356-018-1867-8>.
- [15] Ruben GB, Zhang K, Bao H, Mao X. Application and sensitivity analysis of artificial neural network for prediction of chemical oxygen demand. Water Resour Manage 2018;32:273–83. <https://doi.org/10.1007/s11269-017-1809-0>.
- [16] Neves J, Vicente H, Esteves M, Ferraz F, Abelha A, Machado J, Machado J, Neves J, Ribeiro J, Sampaio L. A deep-big data approach to health care in the AI age. Mobile Netw Appl 2018;23:1123–8. <https://doi.org/10.1007/s11036-018-1071-6>.
- [17] Vicente H, Martins MR, Mendes T, Vilhena J, Grañeda J, Gusmão R, Neves J. A soft computing approach to acute coronary syndrome risk evaluation. Austin J Clin Cardiol 2016;3. Article ID 1044. 8. Available from: <https://austinpublishinggroup.com/clinical-cardiology/fulltext/ajcc-v3-id1044.php>.
- [18] Neves J, Zeleznikow J, Vicente H. Quality of judgment assessment. In: Novais P, Carneiro D, editors. Interdisciplinary perspectives on contemporary conflict resolution, advances in linguistic and communication studies. Hershey: IGI Global; 2016. p. 318–62. <https://doi.org/10.4018/978-1-5225-0245-6.ch006>.
- [19] Nguyen TS, Nguyen LM, Tojo S, Satoh K, Shimazu A. Recurrent neural network-based models for recognizing requisite and effectuation parts in legal texts. Artif Intell Law 2018;26:169–99. <https://doi.org/10.1007/s10506-018-9225-1>.
- [20] Stranieri A, Zeleznikow J. Insights from jurisprudence for machine learning in law. In: Kulkarni S, editor. Machine learning algorithms for problem solving in computational applications: intelligent techniques. Hershey: IGI Global; 2012. p. 85–98. <https://doi.org/10.4018/978-1-4666-1833-6.ch006>.
- [21] Portuguese Ministry of Health. Law 12/2009 of 26 March 2009, vol. 60. Diário da República – 1.ª série. 2009. p. 1876–97. Available from: <https://dre.pt/application/file/a/603284>.
- [22] AABB. American Association of Blood Banks; 2019. Available from: <https://healthfinder.gov/FindServices/Organizations/Organization.aspx?code=HR0147>.
- [23] Cohen L, Manion L, Morrison K. Research methods in education. 8th ed. New York: Routledge; 2017.
- [24] DeKetele J, Roegiers X. Méthodologie du Recueil d'Informations: fondements des Méthodes d'Observation, de Questionnaire, d'Interview et d'Études de documents. 5th ed. Paris: DeBoeck Université; 2016.
- [25] McMillan J, Schumacher S. Research in education: evidence-based inquiry. 7th ed. New York: Prentice Hall; 2009.
- [26] Bell J. Doing your research project: a guide for first-time researchers in education, health and social science. 5th ed. Maidenhead: Open University Press; 2010.
- [27] Fernandes A, Vicente H, Figueiredo M, Neves M, Neves J. An evaluative model to assess the organizational efficiency in training corporations. In: Dang T, Wagner R, Küng J, Thoai N, Takizawa M, Neuhold E, editors. Future data and security engineering, lecture notes in computer science, vol. 10018. Cham: Springer; 2016. p. 415–28. https://doi.org/10.1007/978-3-319-48057-2_29.
- [28] Frank E, Hall M, Witten IH. The WEKA workbench. Online appendix for "data mining: practical machine learning tools and techniques" Morgan Kaufmann. 4th ed.; 2016. Available from: https://www.cs.waikato.ac.nz/ml/weka/Witten_et_al_2016_appendix.pdf.
- [29] Hall M, Frank E, Holmes G, Pfahringer B, Reutemann P, Witten IH. The WEKA data mining software: an update. SIGKDD Explor 2009;11:10–8.
- [30] Souza J, Matwin S, Japkowicz N. Evaluating data mining models: a pattern language. In: Proceedings of 9th conference on pattern language of programs. USA: Illinois. 2002. p. 1–23. Available from: https://hillside.net/plop/plop2002/final/PLoP2002_jtsouza0_1.pdf.
- [31] Ando S, Ono Y, Shimaoka M, Hiruta S, Hattori Y, Hori F, Takeuchi Y. Associations of self estimated workloads with musculoskeletal symptoms among hospital nurses. Occup. Environ Med 2000;57:211–6. <https://doi.org/10.1136/oem.57.3.211>.
- [32] MacDonald LA, Karasek R, Punnett L, Scharf T. Covariation between workplace physical and psychosocial stressors: evidence and implications for occupational health research and prevention. Ergonomics 2001;51:696–718. <https://doi.org/10.1080/00140130119943>.

- [33] Florkowski C. Sensitivity, specificity, receiver-operating characteristic (ROC) curves and likelihood ratios: communicating the performance of diagnostic tests. *Clin Biochem* 2008;29(Suppl. 1):S83–7.
- [34] Vilhena J, Vicente H, Martins MR, Grañeda J, Caldeira F, Gusmão R, Neves J, Neves J. A case-based reasoning view of thrombophilia risk. *J Biomed Inform* 2016;62:265–75. <https://doi.org/10.1016/j.jbi.2016.07.013>.