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Assessing Risks Awareness in Operating Rooms among Post-Graduate Students: A Pilot Study

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Abstract: Background: In this study, we promote a global approach to occupational risk perception in order to improve occupational health and safety training programs. The study investigates the occupational risk perception of operating room healthcare workers using an Analytic Hierarchy Process approach. Methods: A pilot study was carried out through a cross-sectional survey in a university hospital in Southern Italy. An ad hoc questionnaire was administered to enrolled medical post-graduate students working in the operating room. Results: Fifty medical specialists from seven fields (anaesthetists, digestive system surgeons, general surgeons, maxillofacial surgeons, thoracic surgeons, urologists, and gynaecologists) were questioned about perceived occupational risk by themselves. Biological, ionizing radiation, and chemical risks were the most commonly perceived in order of priority (w = 0.300, 0.219, 0.210). Concerning the biological risk, gynaecologists unexpected perceived this risk as less critical (w = 0.2820) than anaesthesiologists (w = 0.3354), which have the lowest perception of the risk of ionizing radiation (w = 0.1657). Conclusions: Prioritization methods could improve risk perception in healthcare settings and help detect training needs and perform sustainable training programs.

Keywords: occupational risk perception; healthcare workers; prioritization risk methodology; Analytic Hierarchy Process

Citation: Corvino, A.R.; Manco, P.; Garzillo, E.M.; Monaco, M.G.L.; Greco, A.; Gerbino, S.; Caputo, F.; Macchiaroli, R.; Lamberti, M. Assessing Risks Awareness in Operating Rooms among Post-Graduate Students: A Pilot Study. *Sustainability* **2021**, *13*, 3860. https://doi.org/10.3390/su13073860

Academic Editor: Flavio Tonelli

Received: 14 February 2021
Accepted: 30 March 2021
Published: 31 March 2021

1. Introduction

The safety, health, and well-being of workers must be ensured in order to work sustainably [1]. To this end, changes must be incorporated into workplace culture and management practices to be sustained over time [2], and it is crucial to create a health and safety prevention culture through sustainable training and job knowledge transmission [3].

Periodical health and safety refresher training is mandated for workers in several employment sectors and is used to maintain and enhance skills when not legally required. Learning is an ongoing process, not isolated to a one-day refresher training session [4].

What could sustainable and adequate training in the field of health and safety in the workplace consist of? On the one hand, sustainable training causes people to continue a defined behaviour indefinitely and demonstrate the training intervention's effectiveness. On the other hand, it may be possible for these workers to learn tomorrow better than they do today.

Through training, workers can learn how to work safely and understand how their health risks are controlled. For that to happen, employees must be included in the risk assessment process and the definition of training needs to be based on a participatory approach.

Workers' risk awareness is the first step in ensuring workplace safety and health [4]. Hence, risk perception and active worker participation in the planning, execution, and evaluation of actual intervention techniques are of great importance [5,6].

A participatory training approach implies starting from the workers' perceptions of risks concerning their job with a double objective. First, it is possible to compare the perceived risk with the assessed risk and identify any aspects not known to the evaluators which are worthy of further study. Furthermore, the workers' knowledge and perceptions make it possible to set up specific and customized training programs. Subsequently, a reassessment of these perceptions can evaluate the effectiveness of the training programs and make improvements.

For this purpose, it is helpful that the methodologies for assessing awareness and the prioritization of risks by workers are standardized and reproducible. Therefore, work safety evaluation should be approached as a Multiple Criteria Decision Making (MCDM) problem. Several methods have been developed, such as the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP) and Goal Programming (GP), for solving selection, allocation, or priority problems. It has been demonstrated that no one method is generally better than the other, but certain methods are more suitable than others for some specific applications [7]. Selection criteria and their relative weights represent the core of many MCDM methods—using set proper criteria and alternatives, their relative importance is deduced by processing numerical measures (judgements) to get a ranking [8].

AHP is undoubtedly one of the most used MCDM tools because it is easy to use and is flexible, so it is usually integrated with various techniques like linear programming and fuzzy logic [9]. The fuzzy AHP (F-AHP) method is a combination of AHP and fuzzy logic. In this case, crisp numbers are replaced with fuzzy numbers. It is usually the preferred tool whenever data and judgements are uncertain or ambiguous [10].

AHP has been widely exploited to select and prioritize risks for the improvement of strategy in industrial contexts and for safety reasons. From the strategy point of view, AHP has been used in supply chain management for evaluating the risk associated with the performance and selection of suppliers [11], for minimizing raw material supply risks and environmental impact [12], and for technology selection and supply chain configuration in sustainable industrial environments [13]. Various studies adopted the AHP method to prioritize safety risks in the construction industry [14,15], but they can also be used in other work contexts. This article reports an experience about the use of AHP to prioritize risks in the operating room.

The operating room is a confined environment characterized by several health and safety risks due to the intrinsic environmental properties, the heterogeneity of the staff competencies involved, the hypothetical acute conditions of patients, the management of large amounts of information, the urgency with which the processes must be performed, the high technological level, and the multiplicity of critical points of the process that are potentially harmful to the patient.

In addition to the standard risk agents evaluated, the operating room also represents a potential exposure to other specific risk factors, linked, for example, to the use of specific equipment for various surgical purposes: some instruments may change the nature of work in the operating room and represent exposure to additional risk factors [16].

Risks include biological [17–19] and chemical agents [20], awkward postures or manual handling of patients with potential biomechanical overload for workers (i.e., on the spine or upper limb) [21,22], ionizing radiation, i.e., the brightness amplifier, such as that used for orthopaedic or urological surgery [23–25]. Finally, transversal risk factors are related to the work organization and the high degree of responsibility associated with the surgical act [26].

In this study, we aim to investigate the perception of occupational risks by operating room healthcare workers (HCWs) to detect training needs and set up a subsequent training

program aimed at the knowledge gaps that have emerged and the use of new technologies such as cross-reality.

2. Materials and Methods

2.1. Study Design, Setting, and Sample

This pilot study consisted of a cross-sectional survey carried out from 1 September 2020 to 31 October 2020 among HCWs from the University Hospital of Campania Luigi Vanvitelli. The sample was selected from residents in the anaesthesia and surgical areas, who usually work in the operating room. Thesixth, fifth, and fourth year post-graduate students were involved, excluding those with less seniority. This choice was dictated by the applied methodology's needs (see Section 2.2) which can be used with expert personnel. The choice of the type of specialization was random, linked to the planning of the health surveillance program, during which the participants were enrolled. The enrolled subjects filled a risk perception questionnaire (see Table S1, Supplementary Materials) based on the AHP methodology.

2.2. Analytic Hierarchy Process

Details about AHP steps and principles can be found in Saaty [27]. AHP is a powerful MCDM method and a user-friendly approach at the same time. It allows for the evaluation of the consistency of judgments. The judges are only required to make a pairwise comparison between criteria without having additional mathematical knowledge. Comparisons are performed using scales of verbal judgments, ranging from values of '1' (equal importance) to '9' (extreme importance). If more than one expert is asked to give the judgements, their judgements have to be aggregated. When using AHP, there are two ways to manage group decision making: the aggregation of individual judgement (AIJ) and individual priorities (AIPs). When the group is intended to act together as an individual AIJ seems to be the suitable solution, whereas if judges act separately based on their own value systems and experience, it has been demonstrated that AIP is the best solution [28]. When experts belong to different disciplines or specializations, their judgements are conditioned by their experience. In this case, it is helpful to aggregate experts' judgments belonging to the same group by adopting the AIJ method. A supra decision maker is needed to characterize the importance of the judges or a group of judges. According to Aly and Vrana [29], the importance of intensity values can be achieved by using a triangular fuzzy linguistic scale in order to take into account the uncertainty of the judgements. An expert, who has enough knowledge of the discipline, is placed in charge of executing pairwise comparisons. A fuzzy positive reciprocal matrix is constructed for each criterion concerning the goal and every type of expert relative to every criterion.

2.3. Ethics

The Ethics Committee of the University of Campania L. Vanvitelli approved the study protocol (No. 20210005512). All HCWs included in the survey were informed by a physician about the survey's rationale and aims, and written informed consent was obtained. Personal information regarding the subjects included in the study is protected according to Italian law [30].

3. Results

This study aimed to evaluate and prioritize the occupational risk perception in surgery. Eight risk drivers were identified as the criteria for an AHP analysis: biological risk, chemical risk, ionizing radiation risk, microclimate risk, biomechanical overload risk, night working risk, structural risk, and fire risk (Figure 1). Fifty physicians, 25 female and 25 male, mean age 31 yo ($\pm$2.48 SD), from seven different fields were asked to perform pairwise comparisons of the criteria against the goal. There were anaesthetists, digestive system surgeons, general surgeons, maxillofacial surgeons, thoracic surgeons, urologists,

and gynaecologists among the experts. Seven enrolled residents reported having had a biological injury (in one case it was SARS-CoV-2 infection).

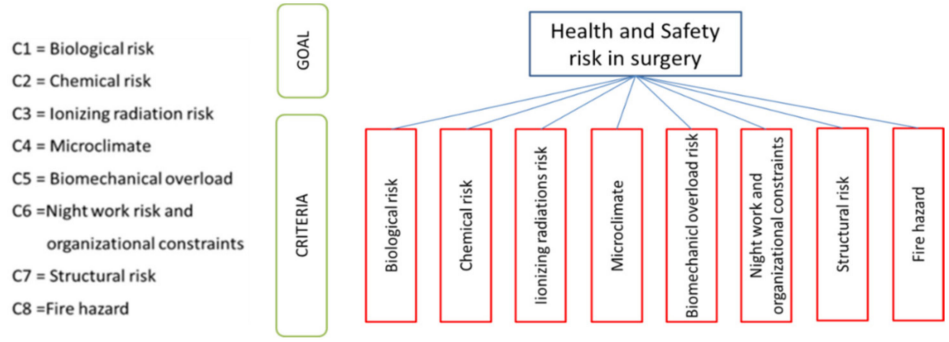

Figure 1. The Analytic Hierarchy Process (AHP) application and criteria definition.

The specialists were separated according to their medical field into seven groups. Once each judge filled out their 8 × 8 matrices, their opinions were aggregated by implementing the AIJ method to obtain seven different pairwise comparison matrices, one for each specialist group. The aggregated matrix resulting from the anaesthetists' judgements is reported in Table 1. In this study, the EGV method was used to derive the weights. Inconsistencies lower than 0.2 were accepted. The priority vectors for each group of specialists are reported in Table 2.

Table 1. Aggregated pairwise comparison matrix for anaesthetist group.

Anaesthetists	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	4.280	3.818	5.456	5.009	6.116	5.614	4.865
C2	0.234	1	4.271	5.813	5.717	5.428	5.666	5.087
C3	0.262	0.234	1	4.898	5.603	5.726	5.762	5.263
C4	0.183	0.172	0.204	1	4.635	4.338	3.932	3.654
C5	0.200	0.175	0.178	0.216	1	4.612	4.448	4.617
C6	0.163	0.184	0.175	0.231	0.217	1	4.247	4.476
C7	0.178	0.176	0.174	0.254	0.225	0.235	1	4.659
C8	0.206	0.197	0.190	0.274	0.217	0.223	0.215	1

Table 2. Priority vectors categorized for each group of specialists.

RF	A	D	G	M-F	T	U	Gy
Biological	0.3354	0.3262	0.3262	0.3043	0.2238	0.3511	0.2820
Chemical	0.2439	0.2177	0.2177	0.2348	0.2051	0.1593	0.2381
Ionizing radiation	0.1657	0.237	0.237	0.246	0.2542	0.2593	0.1811
Microclimate	0.0918	0.0684	0.0684	0.0688	0.0646	0.0571	0.1000
Biomechanical	0.066	0.0525	0.0525	0.0691	0.0632	0.0329	0.0699
Organisational	0.0435	0.043	0.043	0.0365	0.0761	0.0468	0.0545
Structural	0.0312	0.0279	0.0279	0.0207	0.0631	0.0468	0.0379
Fire	0.0224	0.0274	0.0274	0.0199	0.0498	0.0468	0.0366

A = anaesthetists; D = digestive surgeons; G = general surgeons, M-F= maxillofacial surgeons; T = thoracic surgeons; U = urologists; Gy = gynaecologists.

Once the priority vectors for each group were available, the AIP method was chosen to aggregate the weights according to the specialists' perception of the importance of the risk in surgery. The approach described in Section 2.2 was used to determine the important factors to be applied. An expert in occupational medicine was selected to perform the pairwise

comparison. A fuzzy triangular scale was adopted. The hierarchy for the analysis is reported in Figure 2.

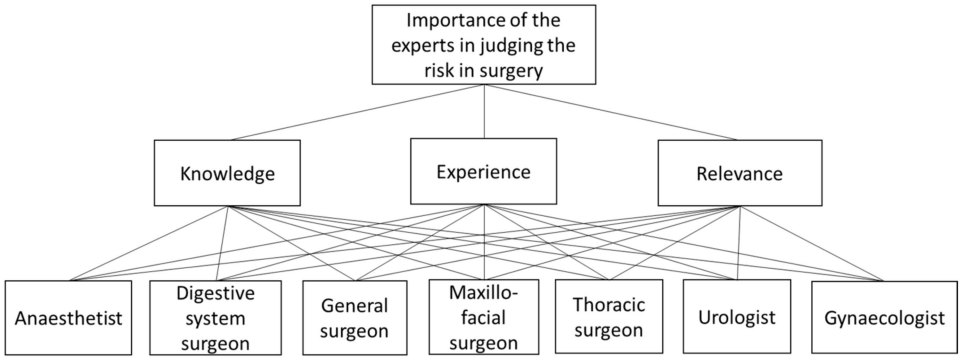

Figure 2. The hierarchy for the prioritization of the judges regarding the analysed problem.

In this study, the criterion "knowledge" represents the cultural background derived from surgery safety training. The experience has to be intended as the first-hand experience of each specialist in surgery. The relevance is simply the amount of information that each specialist was able to collect during the work with regard to the decision problem. The supra decision maker compared the three importance criteria (knowledge, experience, and relevance) regarding the goal; then, the relative importance of each specialization field with respect to every criterion was judged. The outcome of the fuzzy AHP is reported in Table 3. The row at the bottom of this table shows the global weight vector (β) that explains the importance of each group of specialists in the analysis. These values represent the importance of factor β_k, which has to be used in AIP.

Table 3. The outcome of fuzzy AHP analysis for the definition of specialists' importance.

	C vs. G	Anaesthetist	Digestive System Surgeon	General Surgeon	Maxillofacial Surgeon	Thoracic Surgeon	Urologist	Gynaecologist
K	0.324	0.143	0.143	0.143	0.143	0.143	0.143	0.143
E	0.330	0.153	0.148	0.142	0.140	0.140	0.138	0.138
R	0.346	0.148	0.151	0.147	0.146	0.143	0.132	0.132
GW (β_k)		0.148	0.147	0.144	0.143	0.142	0.138	0.138

As can be seen in Table 3, according to the supra decision-maker, the specialists have the same importance concerning the knowledge criterion because the experts have the same training in the security field. The final priority vector, which describes the perception regarding each risk driver was achieved. The weight $w_i^{(G/P)}$ (i = 1, . . . , 8) was obtained by multiplying each row of Table 2 for the transposed global weight vector (β). The final weight is reported in the following table (Table 4).

Table 4. Comparison between specific risks and assessed weight.

Risk Factors	Weight
Biological risk	0.300
Ionizing radiation risk	0.219
Chemical risk	0.211
Microclimate risk	0.071
Biomechanical overload risk	0.055
Night working risk	0.046
Structural risk	0.033
Fire risk	0.030

4. Discussion

Identifying, assessing, and managing health and safety risks is more fundamental than ever for the protection of workers. This process cannot be separated from a participatory approach based on workers' effective information and training systems, especially in the most complex occupational settings, such as healthcare.

In this context, the operating room is a critical operational structure with a combination of several risk factors; thus, it can be defined as a high-risk area [31]. The various professionals working in an operating room (OR) are exposed simultaneously to biological, chemical, physical, ergonomic, and psychosocial risks [32]. Therefore, the prioritization of risks by the workers potentially exposed to them, based on their own perceptions of those risks, can allow us both to review these risks and to create targeted and personalized training programs.

In the healthcare setting, the weight of the risk perception is related to workers' attitudes, due to a specific training over the course of the entire education period. In this study, biological, chemical, and ionizing radiation risks were the perceived most commonly by the HCWs enrolled in the study.

Excluding the ongoing pandemic, data on biological hazard perception are poor [33], and exposure to biological agents is reasonably perceived as a leading risk. Surgeons are at a higher risk than their colleagues from other individual specialities [34]. It must be considered that within the biological risk, the risk of injuries from punctures and cuts have to be included. Indeed, they are the most common accident risks within the operating room and are often correlated with the development of related pathologies, with some differences between countries [35], linked to various factors, probably including different cultural perceptions of risk.

According to collected data, the enrolled sample seemed to have a good perception of this topic of risk, placing it at the top of the scale. Focusing on operating rooms, biological risk perception is often related to sharp and jagged surgical tools and contamination with patients' blood, especially in open surgery. In a 2019 meta-analysis, it was shown that the sharps injury rate in the surgical area was about 1 in 10 operations [36]. Although many workers have the perception of the biological agents in their workplace settings, and thus on the related risk, knowledge on this issue is still lacking, suggesting the need for specific biological risk training to reduce this lack and improve health and safety.

According to Table 2, concerning the biological risk, it also emerged that gynaecologists perceived this risk as less important than anaesthesiologists did, even in the presence of statistically non-significant data. In the authors' opinion, this finding contrasts with the task content, because there should be a higher perception in gynaecologists.

Anaesthetic gas, surgical smoke, and allergic hazards in the operating room represent the main chemical risks for HCWs. The prevalence of occupational dermatitis among healthcare professionals is between 10% and 40%. Significant risk factors for the development of occupational dermopathies are represented by the frequency of handwashing, the use of gloves, personal history of allergy, and the lack of specific training [37]. Therefore, considering the priorities' position obtained through the use of the AHP method and the possible injuries resulting from such exposures, it is essential to stress the concept of targeted training on these aspects.

Respiratory disorders associated with exposure to cleaning products and disinfectants are also increasingly recognized [38]. Although many studies have focused primarily on asthma development, the irritating properties of many chemicals in disinfectants are responsible for a broader range of respiratory effects associated with an increase in chronic obstructive pulmonary disease (COPD) risk and accelerated decline in lung function [39]. However, few studies have investigated the association between occupational exposure to disinfectants/cleaning products and COPD risk among healthcare professionals. Since numerous studies have found that a wide range of disinfectants/detergents can be associated with respiratory problems, it may be necessary to investigate aspects related

to exposure and risk perception. In the enrolled sample, the chemical risk perception was almost similar in all the groups analysed, as shown in Table 2, except for the urologists, who had a minor perception of this risk, perhaps because they carried out more activities with less use of gaseous anaesthetics.

Surgeons are often implicated in radiological procedures; understanding risk perception is essential in order to perform a self-check for any excessive concerns about exposure to ionizing radiations (IRs). There are no uniform or consistent perceptions of radiation risks [40] and there are many misconceptions among medical students and physicians regarding ionizing radiation risk worldwide. Several studies have focused on the lack of dose awareness among medical professionals [40–43]. As shown in Table 4, IRs are the second most perceived risk in the sample, emphasizing that in residents, the perceived risk is high compared to the lack of perception that was observed in the older samples.

Matityahu A et al. highlighted the fact that few well-designed studies focus on surgeons' exposure to radiation, despite its increasing use during surgical procedures [23]. Although the reasons for this lack of health awareness remain unclear, the measures to reduce the potential safety risks associated with IRs exposure are simple [44].

Lee Y. et al. (2021) found that the risk perception of low radiation levels was significantly associated with knowledge levels, which were inversely correlated with radiation risk perception. Moreover, the authors showed that academic degrees were not correlated with risk perception [45].

In this study, data related to risk perception analysed by the AHP method were therefore in line with the prevalent use of IR in these disciplines. Indeed, although this risk was third in the overall prioritization scale, when weighted by the number of subjects enrolled for each discipline, ionizing radiation becomes the second most important risk in digestive endoscopy, urology, thoracic, maxillofacial, and general surgery.

Separate consideration should be made for anaesthesiologists, for whom the lowest risk perception (0.1657) deserves special attention. They represent a medical group working alongside numerous specialists that practising interventional radiology (e.g., haematologists, gastroenterologists, and visiting surgeons). In many cases, anaesthetists operate close to the radiogenic source due to the ergonomic restrictions of their working environments. Moreover, there are specific activities performed by anaesthesiologists that involve the direct use of IRs (e.g., implantation of neurostimulators). Therefore, this working population has a certain degree of exposure to IRs and needs to be adequately trained.

After chemical risk, the weight of perceived risks falls significantly. Among the minor perceived risks, the microclimate was mainly considerate by anaesthetists (see Table 2), perhaps because within the surgical team they carry out activities that are less closely involved with the surgical act, resulting in alert waiting times, which would allow them to focus on the surrounding environment.

Occupational injuries are common in surgery, with two-thirds of all surgeons reporting a work-related musculoskeletal injury during their career, especially orthopaedics [46]. Ergonomics is critical to reducing the risk of injury in settings such as the operating room, where sustained awkward postures, high task repetition, and forceful exertions are commonly seen [47]. To date, few data are available about ergonomic evaluation studies in the operating room [48], with the only studies related to video endoscopic surgery, aiming to improve ergonomics and minimize musculoskeletal injury risks [49]. By contrast, many surgeons suffer chronic musculoskeletal complaints at some point in their careers. This is related to the maintenance of constrained postural positions for many hours in the operating room, increasing their risk of the onset of musculoskeletal disorders [50]. Surgeons need to be trained on the safety of correct body postures to reduce strain on the neck and lower back, as well as on correct patient positioning, and on table height [51].

According to the results of this study and the literature, the risk of biomechanical overload was perceived as less important than it is in reality, which may be because of a prevalence of physicians—rather than nurses or other health professionals—enrolled

in the studies. Nevertheless, it should not be underestimated that this risk perception plays a critical role [52].

In the authors' view, the prevention and reduction in risks should use methodologies and a range of interdisciplinary actions, globally evaluating the work environment and aspects of work processes [53]. By highlighting the risk perception related to a single biomechanical overload task, it might be possible to lead a risk assessment review and modify some incorrect attitudes [54].

Among the less perceived risks were those linked to work organization, particularly to shift and night work. According to recent European survey data, the influence of psychosocial risk factors heavily impacts working conditions. High work demands and poor job organization lead to a lack of support from co-workers and superiors. These situations impact workers' perceptions of health at work and give rise to the feeling that "working is bad for health" in the same proportion as job strain exposure [55]. Simultaneously, the impact of hospitals on occupational safety climate confirms the link between psychosocial risks and overall workers' health [56].

Other minor perceived risks were those concerning the structure of the building in which the subjects worked. Surgeons could often be exposed to burns and scalds from hot water and steam used in sterilizing equipment, electrical shocks from faulty or improperly grounded equipment, or equipment with faulty insulation and noise [57]. For environmental, seismic, fire, electric, and burn hazards, often fewer workers correctly identified the appropriate "what to do" response as compared with both hazard identification and hazard rationale [58].

Recently, scientific investigations have focused on increasing hazard recognition through new technologies in order to improve risk perception. In Albert et al. [59], a high-fidelity virtual environment known as System for Augmented Virtuality Environment Safety (SAVES) was created, which helps develop workers' hazard recognition ability through risk-free learning and immediate feedback. Experience with SAVES has been found to improve hazard perception. The correct recognition of hazards is essential for the development of efficient safety management processes [60].

Regarding prioritization methodologies, even though AHP has a sophisticated mathematical basis, it is known to be very intuitive and relatively easy to apply by using dedicated software tools or algorithms. The decision-maker can rely on a highly organized or numeric dataset to guarantee the availability of the results. In this study, AHP has been used because of its ability to exploit the judgements of several specialists. Since the criteria were known, it was enough simply to identify them for an AHP application. Indeed, it was harder to understand how to aggregate judgements and obtain the "importance factors". The first critical issue in applying the method was to explain the analytical approach and the meaning of the pairwise comparison to the judges. Once the method was clear to them, the second challenge was to implement the method. The procedure that led to the results described in Section 3 was implemented using the Matlab® code and Microsoft Excel® in an integrated manner. The latter was used to aggregate the matrix derived from the judges' pairwise comparison, whereas Matlab® was utilized to codify the AHP procedure. In the scientific literature, AHP is considered to be suitable for group decision-making in health care [61] and risk factor assessments [62]. However, a well-defined methodology to prioritize the risks in surgery in order to focus operations and improve training does not exist. In this work, each step of the procedure and the role of every expert are explained. If these steps are followed with accuracy, the procedure can produce as its output the risk perception in a surgery environment.

AHP and other MCDM methods and their fuzzy versions have already been exploited for occupational health and safety risk assessments in hospital and medical environments. The research that came closest to this study's purpose was carried out by Gul et al. They applied a two-stage fuzzy approach to prioritize the hazard types in six various hospital departments. The decision-makers used the outcomes of the analysis to select protective measures effectively [63].

This study is among the first to introduce the importance of risk prioritization in the healthcare environment. This could have essential practical repercussions such as a more rational intervention in health and safety improvement programs within these workplaces. Thus, according to this method of prioritizing risk, it is possible to improve specific training programs using new technologies, such as augmented reality, to improve risk perception itself [64].

Among the limits of this study, the enrolment of a young sample, with little seniority, could cause a bias in the interpretation of the results, such as the lack of perception of shift-work risk, attributable to differing levels of cognitive fatigue in the young population, which may cope better with night shifts and adapt more easily [65]. The use of young, recruited workers could limit the prospective generalizability of this study to the entire healthcare worker population; however, this is only an apparent limitation, as this paper aims to assess risk perceptions in the period between exiting basic training and the first on-the-job experiences, precisely highlighting the risk perceptions of residents.

Finally, the AHP could be further expanded, perhaps with sub-articulations that provide a detailed study of different exposures to risk agents within a macro-area.

5. Conclusions

Based on prioritizing perceived exposure risks, targeted education and training may help and augment analytical risk evaluations. Furthermore, periodic surveying of the risk perception of exposure risks, including a prioritization method, such as AHP, should be consistently implemented using different methodologies (such as questionnaires and distance learning), thus providing sustainable occupational training, and ensuring well-being.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su13073860/s1, Table S1: Risk perception questionnaire.

Author Contributions: Conceptualization, M.G.L.M., A.R.C., and P.M.; methodology, P.M., and A.G.; analysis, P.M. and A.G.; investigation, A.R.C. and M.L.; data curation, M.G.L.M., E.M.G., A.R.C., and P.M.; writing—original draft preparation, M.G.L.M., E.M.G., A.R.C., and P.M.; writing—review and editing, M.G.L.M. and E.M.G.; supervision, M.L., F.C., S.G. and R.M.; project administration, M.L., F.C., and R.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to a protocol study approved by the Ethics Committee of the University of Campania L. Vanvitelli (No. 20210005512).

Informed Consent Statement: All subjects included in the survey were informed by a physician about the survey's rationale and aims, and a written informed consent was obtained.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to Italian law restrictions.

Acknowledgments: This work was supported by the University of Campania Luigi Vanvitelli under SCISSOR Project—V:alere program 2019.

Conflicts of Interest: The authors declare no conflict of interest.

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