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RESEARCH

Assessment of operating room nurses' exposure to biological hazards: development and psychometric evaluation of a scale

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Abstract

Background Biological hazards are one of the most common threats that operating room personnel face. The present study was conducted to develop and test the psychometric properties of a scale for measuring operating room nurses' exposure to biological hazards.

Methods This study is a methodological research that was conducted in two stages. In the first stage, a pool of items was developed after an extensive literature review. In the second stage, the scale's validity and reliability were tested. The validity of the scale was assessed in terms of face validity, content validity, and construct validity. To determine the scale's reliability, the researchers evaluated internal consistency and stability.

Results The initial version of the exposure to biological hazards scale consisted of 75 items. After assessing face validity, 16 items were eliminated, and one item was added following an evaluation of content validity. In evaluation the construct validity of the scale, three factors were identified that accounted for 66.61% of the variance. The internal consistency of the scale was confirmed with a Cronbach's alpha of 0.88. Additionally, the split-half correlation coefficient was found to be 0.92, and an intraclass correlation coefficient (ICC) of 0.96 confirmed the stability of the scale.

Conclusion The results of the study show that the developed scale has satisfactory reliability and validity. Nursing managers can use it to assess operating room nurses' exposure to biological hazards in the workplace.

Keywords Scale development, Psychometric properties, Biological hazards, Operating room nurses

Introduction

Workplace accidents are the third most common cause of death in the world and the second leading cause of death in Iran after car accidents [1, 2]. The International Labor Organization reports that one person loses his/her life as a result of a work-related incident or illness every 15 s worldwide [3]. Healthcare personnel constitute 12% of the global workforce [4]. According to the American Society of Safety Engineers (ASSE), hospital personnel are 41% more at risk of work-related illnesses and injuries compared to individuals in other professions [5]. Among hospital departments, operating rooms stand

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out due to their unique structure and work conditions. The dynamic, unpredictable, and stressful environment, complex systems and long working hours have a negative impact on the health of operating room personnel [6]. These personnel are constantly exposed to physical, ergonomic, biological, chemical, and psychological hazards [6, 7]. Previous research indicates that biological hazards are among the most prevalent risks in operating rooms [8, 9].

Contact with patients' blood and its components, urine, feces, exudate, secreted fluids, vomit, and objects infected with them is the most common cause of biological contamination among operating room personnel [7]. Healthcare workers (HCWs), especially those in the operating room, are at risk of injuries from sharp objects and blood-borne pathogens [10]. The annual incidence of skin injuries is 31.8% in Europe [11] and 42.5% in Iran [12]. The most dangerous blood-borne pathogens include HBV, HCV, and HIV. A study in Iran found that nurses experience the most injuries from sharp objects among healthcare professionals [13], and suture needles are the most common cause [14]. Another study revealed that operating room personnel's perceived level of knowledge and self-efficacy in preventing injuries from sharp objects was unsatisfactory [15].

Another source of biological hazards in the operating room is nurses' exposure to patients' blood and body fluids (BBF) [16]. The global rates of BBF exposures among healthcare personnel during their working years and in the preceding year were 56.6% and 39.0% respectively [17]. One study found that failure to use safety glasses and lack of training in infection prevention were the primary risk factors in healthcare personnel's BBF exposure [18].

After searching in different databases, the researchers could not find a scale that comprehensively measures operating room nurses' exposure to biological hazards. Therefore, the present study was conducted to develop and test the psychometric properties of a scale for measuring operating room nurses' exposure to biological hazards.

Methods

Study design

This study was conducted in the largest city in southern Iran throughout 2023. In the initial stage of this methodological study, researchers conducted a thorough literature review to compile a list of biological hazards that endanger the health of operating room personnel and created the initial pool of items. The databases of Scopus, PubMed, Web of Science, Embase, and Science Direct were searched for articles using keywords such as "occupational injuries," "biological hazards," "needle stick," "blood and body fluid exposure," "biological air pollutants," "operating room," and "nurses" both individually and in combination. In the next step, three researchers reviewed the obtained titles and removed duplicates ($n=12$). Then, the abstract and full text of the studies were reviewed, and any studies lacking full text or not aligning with the study's purpose were excluded ($n=19$). Finally, the remaining studies ($n=22$) were used for item development (see Fig. 1). After generating the initial items, the researchers held several meetings with a panel of experts consisting of 10 members, including operating room, occupational health, and scale development experts. The items were carefully examined during these meetings. Irrelevant items were eliminated, similar items were merged, and some items were added to the scale. In the second stage of the study, the validity and reliability of the scale were measured.

Evaluation of the psychometric properties of the scale

Participants and the study setting

Throughout the study, researchers used a panel of experts in various stages. The size of the expert panel is usually between 3 and 12 people [19]. In the present study, 10 experts participated in the item generation stage, and a panel of 15 individuals was used for the psychometric evaluation stage (face and content validity). The criteria for selecting expert panel members for face and content validity included interest in participating in the study, knowledge and experience of working in the operating room, familiarity with the desired concept, and expertise in instrument developing. For exploratory factor analysis (EFA), there is no consensus on sample size. For example, MacCallum et al. (1999) suggest a sample size of 200 participants [20], Munro (2005) suggests 5 to 10 samples per item [21], and Ebadi et al. (2017) suggest 4 to 10 samples per item [22]. In the present study, more than 10 nurses working in hospitals affiliated with Shiraz University of Medical Sciences were selected for each item on the 25-item scale for the EFA. Researchers selected participants from various age, gender and educational groups in order to prevent bias, using maximum variation sampling. The inclusion criteria for nurses in the evaluation of construct validity were having at least an associate degree and a minimum of one year of experience in operating rooms. Nurses who did not complete the questionnaires were excluded.

Validity analysis

Face validity

In the present study, researchers utilized evaluation methods for face validity, content validity, and construct validity. For the qualitative evaluation of face validity, 10 operating room nurses, four faculty members, and one occupational health expert were interviewed to evaluate the items in terms of ambiguity, relevance, and difficulty.

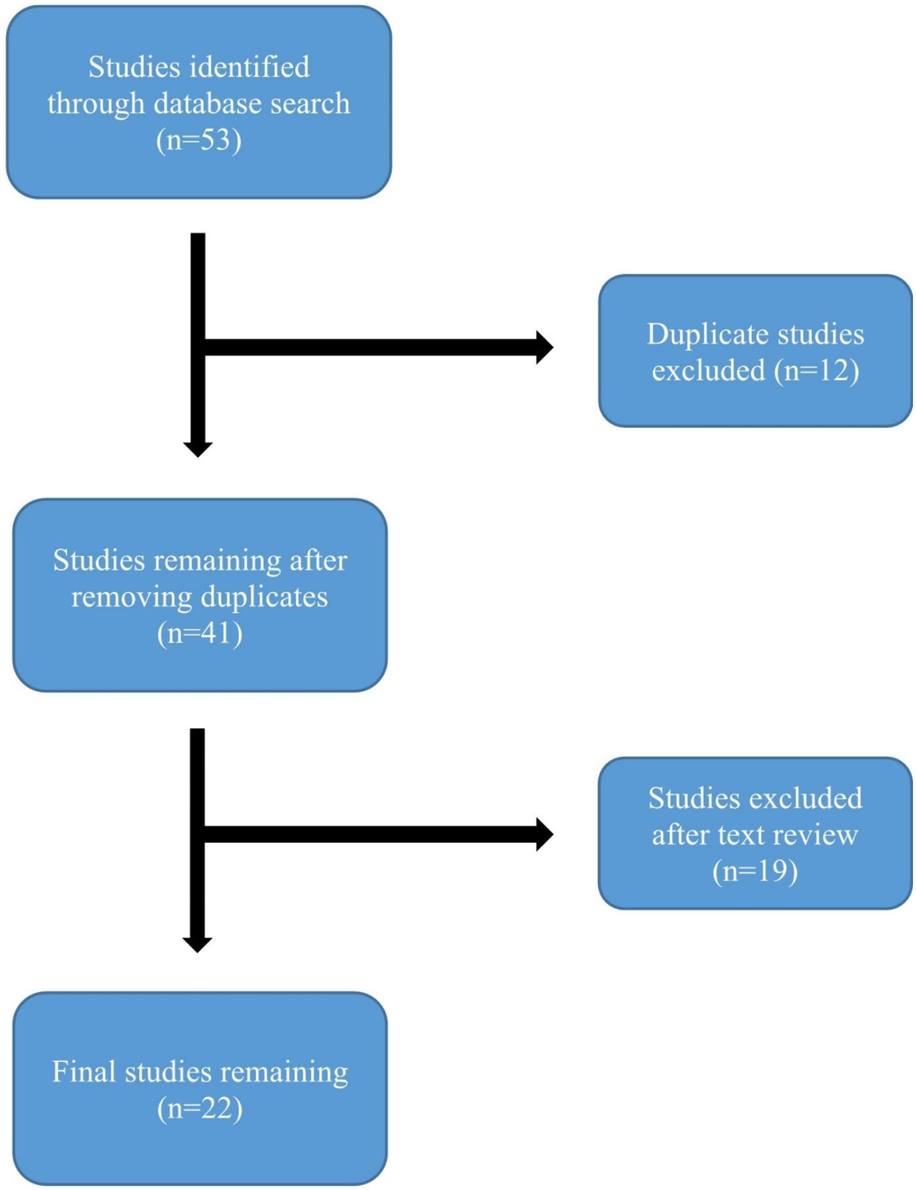

Fig. 1 Flow chart for the selection of studies in the literature review

In the quantitative evaluation of face validity, 15 operating room nurses were asked to determine the significance of the items on the scale using impact scores (IS). Items with an IS less than 1.5 were eliminated [23].

Content validity

For the qualitative evaluation of content validity, feedback was gathered from 10 operating room nurses, three faculty members, and two scale development experts who were knowledgeable about the research subject. They were asked to provide feedback on the wording, scoring, and order of the items. In addition to the qualitative evaluation, the researchers also conducted a quantitative evaluation of content validity. This involved measuring the content validity ratio (CVR), content validity index (CVI), and scale-level content validity index (S-CVI) of the scale.

Construct validity

The construct validity of the present scale was assessed using two methods: Exploratory factor analysis and calculation of convergent validity. Before conducting EFA, the researchers performed item analysis with a sample of 40 individuals. They examined the correlation among the items, the correlation between the items and the total score, and the instrument's reliability using Cronbach's alpha. In the initial phase of EFA, the Kaiser-Meyer-Olkin (KMO) test was utilized to confirm sampling adequacy, with values above 0.8 considered appropriate [24]. Bartlett's sphericity test was used to evaluate the correlation matrix of the scale. In the subsequent phase of EFA, factors were identified using eigenvalues and a scree plot. To simplify and enhance the interpretability of the factor construct, varimax rotation was applied by the researchers. At this point, the sample size was set at 300 individuals, which is more than 10 times the number of items. The minimum factor loading for the items to be retained was set at 0.5. Items with factor loadings less than 0.5 were eliminated.

The convergent validity of the developed scale was tested using the operating room nurses' exposure to chemical hazards scale [25]. Convergent validity examines the similarity of different constructs in measuring the same trait. To assess this, a scale is used that shares the same content as the scale being evaluated psychometrically [19]. The scale used to measure exposure to chemical hazards in operating room nurses, like the current scale, assesses one of the risks faced by these nurses. Therefore, the mentioned scale was utilized to test convergent validity in this study. The correlation between the scores of these two scales can indicate the validity of the present scale. Both scales were simultaneously given to 100 operating room nurses and the correlation between them was calculated using the Pearson correlation coefficient.

Reliability

In the present study, reliability was assessed based on the internal consistency and stability of the scale. Internal consistency was determined by calculating Cronbach's alpha and using the split-half method. A Cronbach's alpha of 0.7 to 0.8 indicates acceptable internal consistency [26]. In the split-half method, the scale items were split into odd-numbered and even-numbered groups, and the correlation between them was calculated using the Guttman split-half coefficient. Correlation coefficients above 0.7 were considered satisfactory.

To assess the stability of the instrument, the researchers conducted a test-retest and calculated the ICC of the scale. Forty operating room nurses completed the scale twice with a 14-day interval. The ICC between the respondents' scores from the two stages was then calculated. Correlation coefficients higher than 0.75 were considered satisfactory [27].

Ethical considerations

Before being conducted, the study was approved by the ethics committee in biomedical research at Shiraz University of Medical Sciences (ethics code: IR.SUMS.NUMIMG.REC.1401.058). All participants were informed about the study's objectives, and their names were replaced by codes to ensure confidentiality. Additionally, all participants signed the informed consent form.

Results

The majority of the participants were female (61.7%), married (55.3%), had a bachelor's degree (83%), and were aged 26 to 36 years. Table 1 displays the demographic characteristics of the participants during the evaluation stage of construct validity.

Table 1 Personal characteristics of the participants in the construct validity ($N = 300$)

Variable		Absolute frequency	Relative distribution (%)
Age (years)	Under 25	57	19
	26–30	104	34.6
	31–35	71	23.6
	36–40	43	14.4
	Over 40	25	8.4
Gender	Male	115	38.3
	Female	185	61.7
Marital status	Married	166	55.3
	Single	134	44.7
Education	Associate degree in operating room nursing	22	7.3
	Bachelor degree in operating room nursing	249	83
	Master degree in operating room nursing	29	9.7
Professional experience (years)	Under 5	132	44
	6–10	80	26.6
	Over 11	88	29.4

Development of the initial items

After conducting a thorough literature review, a total of 75 items were initially identified. These items were then reviewed by a panel of experts in multiple meetings, leading to the removal of 29 items and the merging of 12 others. At the conclusion of this stage, the scale consisted of 40 items.

Evaluation of the psychometric properties of the scale

Validity

In the qualitative evaluation of face validity, some items were revised and seven items were eliminated. In the quantitative evaluation of face validity, nine items were found to have an IS of less than 1.5 and were therefore eliminated, reducing the total number of items to 24.

In the qualitative evaluation of content validity, a few items were revised and one item was added to the scale. In the quantitative evaluation of content validity, all items had a CVR greater than 0.49, which is considered significant ($P < 0.05$) [28]. Additionally, all items had a CVI greater than 0.79, confirming their relevance, clarity, and simplicity [22]. The SCVI/UA and SCVI/Ave of the scale were 0.84 and 0.98 respectively, demonstrating satisfactory overall content validity [29]. At this point, none of the items were eliminated, and the total number of items reached 25.

The results of the item analysis showed that all items on the scale had a correlation of greater than 0.3 with at least one other item, and that no two items had a correlation of greater than 0.7. Additionally, the correlation between all items and the overall score of the scale was greater than 0.3. The reliability of the instrument at this point was found to be a satisfactory 0.8, so the scale remained unchanged before conducting exploratory factor analysis.

In the present study, a factor loading of 0.5 was considered the lowest acceptable degree of correlation between each item and the extracted factors. All items on the scale had a factor loading higher than 0.5, so none were removed. Items with high correlation were grouped into one factor or category. The sampling adequacy of the scale was confirmed with a KMO statistic value of 0.892. Additionally, Bartlett's test of sphericity yielded a significant result with a chi-square of 4313.383 and 300 degrees of freedom at $P<0.001$. Therefore, the results of Bartlett's test supported those of the KMO test. In exploratory factor analysis using an eigenvalue greater than 1, five factors were identified, explaining 66.61% of the scale's variance. The first factor included items 12 to 22, explaining 26.246% of the variance, related to operating room nurses' exposure to blood and infected body fluids, named "exposure to blood and infected body fluids." The second factor, "exposure to sharp objects," included items 1, 2, 3, 4, 5, 7, 8, 9, 10, and 11, accounting for 22.516% of the variance. The third factor, "exposure to biological air pollutants," included items 24 and 25, accounting for 6.960% of the variance. Factors four and five, explaining 6.077% and 4.817% of the variance respectively, consisted of one item each. Item 6, related to injuries caused by sharp objects, was moved from factor 4 to factor 2. Additionally, item 23, related to exposure to blood and infected body fluids, was moved from factor 5 to factor 1 (Table 2).

The scree plot revealed that there were three factors in the scale measuring operating room nurses' exposure to biological hazards (Fig. 2). An assessment of the scale's convergent validity indicated a positive and significant correlation between the current scale and the

Table 2 Grouping the items of the questionnaire based on the results of factor analysis

Categories	Items	Factor loadings
exposure to blood and body fluids	12. I wear gloves to handle the operating bed, the patients' bodies, or samples.	0.814
	13. After removing my gloves, I immediately wash my hands.	0.816
	14. Even if my hands are wounded, I scrub and take part in surgery.	0.683
	15. Before surgical procedures in which fluids or bone pieces may be thrown around, I use protective equipment, e.g. glasses, waterproof aprons, boots, and shoe covers.	0.798
	16. At the end of surgery, I first remove my gown and then my gloves.	0.752
	17. I wash contaminated instruments in the scrub room sink.	0.771
	18. I mark the tool sets used for patients with an infectious disease.	0.735
	19. I sanitize my shoes if they are contaminated by a patient's blood or fluids.	0.827
	20. At the end of my shift, I place my scrub uniform in the laundry basket to be washed.	0.654
	21. I sanitize my cellphone when I enter and before I leave the operating room.	0.739
	22. I eat and drink in the operating room.	0.772
	23. After surgery on a patient with an infectious disease, I use the same room for surgery on a patient with a non-infectious disease.	0.736
exposure to sharp objects	1. When I am scrubbing for high-risk surgeries, I use double glove or protective gloves.	0.836
	2. I always dispose of all sharp objects (e.g. needles, scalpels, pins, and tips of cautery pens) in the safety box after use.	0.772
	3. I dispose of sharp objects in the safety box by hand.	0.784
	4. I collect the sharp objects lying on the operating room floor.	0.630
	5. I place scalpels on the scalpel holder by hand.	0.692
	6. I place needles on the needle holder by hand.	0.597
	7. During surgery, I use free-hand techniques to transfer sharp objects.	0.623
	8. At the end of surgery, I separate sharp objects (e.g. scissors and osteotomes) from the other instruments.	0.660
	9. I report injuries by sharp objects to the supervisors in charge.	0.755
	10. I wear closed-in shoes in the operating room.	0.751
	11. When the trash can is full, I compress the waste by hand or foot.	0.652
exposure to biological air pollutants	24. During surgeries which involve intense exposure to surgical smoke, I wear high-filtration (N 95) masks.	0.886
	25. I use a proper extractor to remove surgical smoke, e.g. electrosurgery smoke, from the operating room.	0.880

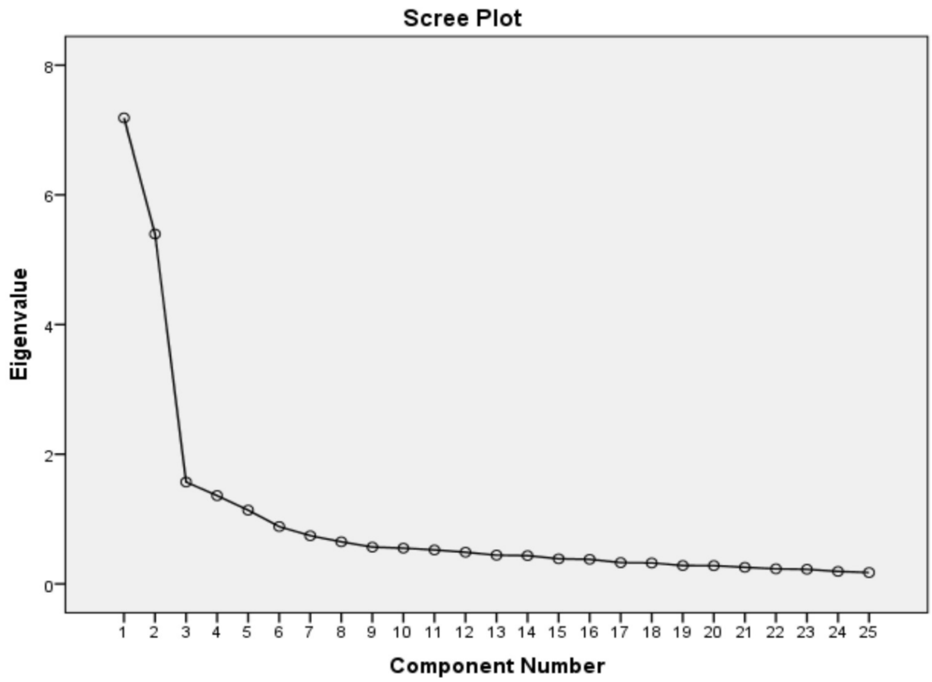

Fig. 2 The factor analysis scree plot

scale measuring operating room personnel's exposure to chemical hazards ($P=0.002$, $r=0.507$), confirming the convergent validity of the present scale.

Reliability

The internal consistency of the present scale was verified by Cronbach's alpha and split-half correlation coefficient of 0.88 and 0.92 respectively. In addition, an ICC of 0.96 from the test-retest indicated that the scale had very good stability.

Discussion

This study offers a comprehensive and validated scale that fills the gap in assessing operating room nurses' exposure to biological hazards, a previously unmet need in clinical practice.

Items 1 to 11 focus on exposure to sharp objects in the operating room. Previous studies have shown that injuries caused by sharp objects are more common in operating rooms compared to other hospital departments [30, 31]. A report from the United States Food and Drug Administration (U.S. FDA) in 2012 stated that 23% of the 384,000 needlestick injuries that occur in hospitals annually happen in operating rooms [32]. In one study, 81.7% of participants reported being exposed to a sharp object at least once in the past year, with 66.7% of these injuries occurring to operating room personnel while handling suture needles [31]. In another study, one of the three main causes of injuries caused by sharp objects was placing suture needles in needle holders. Additionally, only 4.6% of the personnel reported injuries from sharp objects, highlighting a significant issue in the healthcare system [33]. A study by Amiri et al. (2022) identified the application of sharp pins in orthopedic surgeries as another source of injuries to personnel [34]. Preventive measures such as designating a specific place for sharp objects on the operating room table as determined by the surgeon, wearing two layers of gloves for all surgeries, informing surgical team members about protocols for handling sharp objects, and using forceps to place needles in the needle holder are often overlooked by operating room personnel and therefore need to be emphasized [15]. One preventive measure is using the hand-free technique for moving sharp surgical tools [31]. In this method, the surgeon and nurses select a safe zone on the operating room table or a tray where the sharp tools are to be placed and taken from. This ensures that no two members of the surgical team will touch a sharp object simultaneously [35, 36]. By utilizing this technique, the risk of injury to scrub nurses and surgeons is minimized as they will not pass sharp tools by hand.

Items 12 to 23 address exposure to blood and body fluids. These exposures often occur during procedures such as taking blood samples, giving injections, suturing wounds, assisting in childbirth, providing emergency care, and sanitizing contaminated tools [37]. A study in Cyprus identified exposure to blood, blood components, and contaminated body fluids as one of the three major risk factors that nurses were well aware of in dangerous situations [38]. One of the most important ways to prevent exposure to such fluids is through the effective use of personal protective equipment [39]], which protects the personnel's hands, eyes, clothes, hair, and shoes from contamination by microorganisms [40]. In a study conducted in India, it was found that all operating room personnel used gloves, masks, aprons, gowns, and caps. However, only a small percentage of them used safety glasses (7.3%) and shoe covers (8.3%). This lack of usage could be attributed to the unavailability of this equipment and the personnel's lack of awareness regarding its importance [41]. Another preventive measure is to wash hands after removing gloves, remove gowns before gloves, avoid using the scrub room sink for washing contaminated tools, and refrain from entering the surgical environment if there are open wounds on one's hands [39]. According to a study conducted in Iran, it was found that due to the lack of a designated room for washing contaminated tools before transferring them to the sterile set room, personnel were washing these tools in the scrub room sink. This practice was spreading infections in the scrub room environment and sinks [34].

Items 23 and 24 are related to biological air pollutants in the operating room. Operating rooms are specialized units that require clean air with minimal microorganisms [42]. Factors that influence the air quality in operating rooms include the number of people in the room, human activities, the type of garments worn by personnel, and how often the doors are opened and closed [43]. One of the most hazardous air pollutants in operating rooms is surgical smoke [44, 45]. The results of a study in Iran showed that 93.6% of operating room nurses had poor awareness of the dangers of electrosurgery smoke, with only 0.4% well aware of these dangers. Additionally, the study reported that 94.7% of participants did not use proper masks during electrosurgery [46]. To prevent personnel exposure to surgical smoke, operating rooms must be equipped with smoke extractors, and personnel must wear tight and efficient masks [47]. Smoke extraction systems in operating rooms can significantly decrease the concentration of organic compounds in the air [48]. Furthermore, researchers emphasize that high-filtration masks (N95) can prevent exposure to surgical smoke [49].

In the current study, the construct validity of the instrument was assessed through exploratory factor analysis. This type of analysis is used to determine the method of factor extraction, the number of factors for confirmatory factor analysis (CFA), and the rotation method. Since the factors defining the concept of interest were unclear, conducting exploratory factor analysis was necessary. It is important to note that there is no clear boundary between exploratory factor analysis and confirmatory factor analysis, and both methods falling on a spectrum from exploration to confirmation. While the present study achieved its goals through exploratory factor analysis, future studies should aim to further evaluate and validate the components of the instrument to enhance its utility and strengthen its psychometric properties.

The items of the present scale are scored on a 5-point Likert scale: Always=1, Most of the time=2, sometimes=3, Seldom=4, and Never=5. Items 3, 5, 6, 11, 14, 17, 22, and 23 are scored in reverse. The lowest and highest possible scores are 25 and 125 respectively. Respondents' overall scores are evaluated using a three-part scale. The instrument's cut-off point is set at 33. A score of 25 to 58 indicates low exposure, 59 to 91 indicates moderate exposure, and 92 to 125 indicates severe exposure to biological hazards in the operating room.

Limitation

Participants in this study were selected from hospitals in one city based on specific inclusion criteria. Therefore, the findings of this study may not be generalizable to other countries. However, since the items of the instrument were extracted after an extensive literature review, it appears that this instrument can be used for other communities as well. It is recommended that future studies be conducted to validate the instrument in different settings.

Conclusion

Operating room personnel work in a complex and unpredictable environment with various biological hazards. Operating room nurses must adhere to protocols designed to prevent their exposure to biological hazards and nurse managers should regularly measure nurses' exposure to these threats using standard instruments. The present scale (Appendix 1) is a valid and reliable instrument that determines operating room nurses' exposure to biological hazards. Nursing managers can use this instrument to identify weaknesses in operating rooms, develop plans to improve the current situation, and minimize the risk of injuries caused by these hazards.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12912-024-02560-1.

Supplementary Material 1

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Author contributions
CT was responsible for the study conceptualization and performed the data curation. CT and MB performed the investigation, methodology and supervised the study. MB, MA and YA were responsible for data collection and analysis. CT and MB led the writing of the manuscript. All authors helped to reviewing and editing of the manuscript.

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Data availability
If needed, the corresponding author will provide access to the data used in the study.

Declarations

Ethics approval and consent to participate
The present study was approved by the ethics committee in biomedical research at Shiraz University of Medical Sciences (ethics code: IR.SUMS.NUMIMG.REC.1401.058). All participants were informed about the study's objectives, and their names were replaced by codes to ensure confidentiality. Additionally, all participants signed the informed consent form.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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