Development and Validation of HOSHRA Index for Occupational Safety and Health Risk Assessment in Hospitals

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Abstract

**Background:** Despite huge advances in science, technology, and medical equipment, numerous concerns grow over healthcare workers (HCWs) since they are exposed to a wide range of biological hazards due to the nature of their work.

**Objectives:** The current study aimed at developing and validating an index to assess the risk of occupational safety and health (OSH) in hospitals and healthcare settings.

**Methods:** In the current cross-sectional study, an index called the hospital occupational safety, and health risk assessment (HOSHRA) was developed and validated through the face and content validity as well as internal consistency and inter-rater reliability. Ultimately, the developed index was utilized to assess OSH risks in 36 teaching hospitals affiliated to Shiraz University of Medical Sciences, Shiraz, Iran.

**Results:** The mean score of the HOSHRA index among the selected hospitals was $71.53 \pm 5.93$, indicating that the OSH risks were at a moderate level. According to the HOSHRA action levels, OSH risk level for ergonomic hazards was high, but it was moderate for physical, chemical, ergonomic, and psychological ones. In terms of physical hazard subcategories, the risk of electrical hazard, as well as fire and explosion, was high, but it was moderate for fall and slip, and radiation.

**Conclusions:** The developed observation-based method showed an acceptable content validity and reliability for OSH risk assessment of hospitals. The HOSHRA index could also be used for hospitals as an applicable measure to improve their OSH.

Keywords: Hospital, Occupational Health, Safety, Risk Assessment

1. Background

Despite huge advances in science, technology, and medical equipment, numerous concerns grow over healthcare workers (HCWs) since they are exposed to a wide range of chemical, biological, mechanical, physical, and psychological hazards due to the nature of their work. The presence of different hazards in hospitals is repeatedly mentioned in many studies; for example, electric shock due to increased use of diagnostic and therapeutic equipment such as electrocardiogram and electric suction devices (1), chemical hazards observed after being exposed to disinfectants, cleaning compounds, drugs, mercury, and anesthetic gases (2, 3), fire and explosion caused by increasing fire risks with the development of vertical buildings (4), as well as the use of pressure devices and heaters (5, 6), slips and falls due to unsafe surfaces (7), exposure to radiation following the use of radiant and radioactive materials for diagnostic and therapeutic purposes (7), hospital waste produced by microorganisms (8, 9), injury with needles and sharp objects accompanied by contamination with pathogens including hepatitis B, C, and human immunodeficiency viruses (10), respiratory disorders and lung function impairments due to exposure to chemical and bioaerosols (11), musculoskeletal disorders as one of the most common causes of absenteeism and injury among HCWs particularly females (12, 13), and psychological risks such as job stress (14), shiftwork (15), and violence in the workplace (16).

Since health-related hazards and challenges in hospitals are considered as unique risks, HCWs and nurses are at risk of experiencing different kinds of health problems as well as some accidents and natural disasters. In 2013, 19% of all recorded occupational diseases in the United States oc-
2. Objectives

The current study aimed at developing and validating a particular index for OSH to improve the safety of healthcare systems more effectively.

3. Methods

The current cross-sectional study was conducted in two phases.

3.1. Development and Validation of the Hospital OSH Risk Assessment Index

3.1.1. Preparing Hazard Identification Checklists

In order to develop and validate an index applicable to healthcare centers, firstly, effective items on these fields had to be identified and categorized. In the present study, the research team referred to the selected hospitals at certain times. Prior to visiting the given hospitals, coordination was made with hospital authorities, and necessary permissions were also obtained. A package of the HAZID checklists were then provided considering five occupational hazard categories including physical (electrical, fire/explosion, fall/slip, and radiation), chemical (exposure to acids and bases, alcohol, ether, ester, formaldehyde, and detergents), biological (needle stick and sharp objects, hospital waste, and bloodborne pathogens), ergonomic (musculoskeletal disorders and environmental parameters), and psychological hazards (violence in the workplace, shiftwork, and job stress). The items included in the checklists were extracted from the national OSH regulations and standards for each category as well as national guidelines. A total of 10 OSH experts with at least five years of experience in healthcare settings were then interviewed and asked to study the items and provide comments on them. Afterward, the comments were applied to the considered items. Table 1 indicates a summary of the items selected for each hazard category.

3.1.2. Validity and Reliability of HAZID Checklists

To assess the face validity of the HAZID checklists, the first version of the prepared checklists were examined by OSH experts in terms of relevance, clarity, and simplicity. Moreover, they were asked to leave comments on the items and also add any other items they thought were required for the HAZID checklists in hospital settings. The content validity ratio (CVR) was also calculated for each item of the checklists, according to Lawshe’s formula (24, 25) (Equation 1). In this respect, a panel of experts was created, and they were asked to rate each item based on a three-point Likert scale as 0 (not essential), 1 (useful, but not essential), and 2 (essential).

\[
CVR = \frac{n_e - N}{2} \div \frac{1}{2}
\]  

CVR: Content validity ratio (to analyze the validity of items)

\(n_e\): Number of panelists essential to each item of the HAZID checklists

N: Total number of panelists

According to Lawshe (24), a CVR of 0.62 is required to retain the item when there are 10 panelists. Content va-
Safety maintenance principles of chemicals, training HCWs in safe injection, principles of waste management, radiation hazard warning signs, use of radiation protection equipment, stress reduction programs, clarified duties of staff, was assessed based on the following criteria: acceptable inter-rater reliability (27). Cronbach’s alpha coefficient was used to assess the internal consistency of the checklists for hazard categories, which was ≤0.7, indicating good internal consistency (28).

### 3.1.3. Determining Importance Coefficient of Items

To weigh the importance of each item in the HAZID checklists, a coefficient scored 1 (minimum importance) to 3 (maximum importance) was allocated to each item. This coefficient was determined based on the judgments of a panel of experts consisting of 10 OSH experts in hospitals.

To determine the IC, the mean score of panelists’ scores for each item was interpreted as 1 - 1.5 (IC = 1), 1.6 - 2.5 (IC = 2), and 2.6 - 3 (IC = 3).

### 3.1.4. Weighing Hazard Categories Using Analytical Hierarchy Process

In the current study, the weight of different hazards in hospital settings was calculated through AHP. This method was developed by Saaty (29) to support multi-criteria decision-making when the problem could be broken down into its constitutive elements through which decision-making would be possible based on paired comparisons, and various options could also be prioritized based on specified criteria (30). Both of the two phases of the AHP technique, including hierarchy tree definition and numerical evaluation of tree, were completed in the current study. The hierarchy tree definition, therefore, started from the determination of the proposed goal, and then the criteria (i.e., severity, and likelihood of hazards) were defined using the expert’s experience. For this purpose, all five categories and four subcategories of hospital hazards were included in paired comparison questionnaires and submitted to the 10 OSH experts experienced in hospital settings. They were subsequently asked to weigh the severity and probability of each pair of hazards using the Saaty scale. Therefore, the alternatives (i.e., different hazard categories) were prioritized in the evaluation phase of the AHP technique based on paired comparisons (31, 32).

This process was performed to obtain values that weigh criteria and define a ranking for alternatives. The
evaluation was also bottom-up in a way that the decision-making process started by comparing the alternatives with the criteria of the last level. The evaluation continued up to the criteria of the 1st level, which were then compared with the goal.

The scheme proposed by Saaty (i.e., equal 1, barely better 2, weakly better 3, moderately better 4, definitely better 5, strongly better 6, very strongly better 7, critically better 8, absolutely better 9) was further used to translate linguistic judgments into numbers (33, 34). Finally, the geometric mean of the responses was calculated, and the weight (i.e., risk) of each hazard was provided using the Super Decisions software.

3.1.5. Completion of Checklists and Scoring
In this phase, all the 36 teaching hospitals affiliated to Shiraz University of Medical Sciences were evaluated by five trained observers using the developed index. For this purpose, 10 random workstations were considered to be observed in each hospital. Each item of the HAZID checklists was comprised of two columns in front, including safe and unsafe. Each item was also scored based on the number of checkmarks in the safe column as follows: 2 (complete safety) for more than seven checkmarks, 1 (incomplete safety) for 4 - 7 checkmarks, and 0 (unsafe) for 1 - 3 checkmarks in the safe column in front of each item. The score for each checklist (i.e., hazard category/subcategory) was calculated using Equation 3 (35):

\[ N = \frac{\sum x_i n_i}{\sum 2n_i} \times 100 \]  

where:
- \( N \): Score of each checklist (i.e., hazard category/subcategory)
- \( n_i \): IC of the item
- \( x_i \): Calculated score for each item

Finally, the HOSHRA index was computed using Equation 4:

\[ HOSHRA = \sum N_c \times W_c \]  

where:
- \( N_c \): Calculated score for physical, chemical, biological, ergonomic, and psychological hazard categories
- \( W_c \): Inter-category AHP weighted coefficient

For the physical hazard category consisting of four subcategories, the risk of electrical shock along with fire and explosion hazards was high, but it was moderate for physical, chemical, ergonomic, and psychological ones. In the physical hazard subcategories, the risk of electrical shock along with fire and explosion hazards was high, but it was moderate for fall and slip, and radiation.

4. Results

The calculated CVI, ICC, and Cronbach’s alpha coefficient indicated an acceptable content validity, inter-rater reliability, and internal consistency for hazard categories (Table 2). Figure 2 illustrates the intra-category AHP weighted coefficient for physical hazard subcategories and hazard categories. As shown, based on the panelists’ point of view, fall and slip had the highest weighted coefficient, followed by radiation hazard among the physical hazards (Figure 2A). Furthermore, among the main hazard categories, the highest values of the AHP weighted coefficient were assigned to biological hazards (Figure 2B).

Table 3 represents the mean scores of the HOSHRA index for hazard categories in the studied hospitals. As reported, ergonomic hazards had the lowest value in the HOSHRA index, indicating the highest level of OSH risk among the hazard categories. According to the HOSHRA action levels, the level of OSH risk for ergonomic hazards was high, but it was moderate for physical, chemical, ergonomic, and psychological ones. In the physical hazard subcategories, the risk of electrical shock along with fire and explosion hazards was high, but it was moderate for fall and slip, and radiation.

5. Discussion

The current study mainly aimed at assessing OSH risks among hospitals in Shiraz, Iran. To this end, an observation-based method, named the HOSHRA index, was developed. The index consisted of a package of eight HAZID checklists in five categories of physical, chemical, biological, ergonomic, and psychological hazards. The developed HOSHRA index showed acceptable validity and reliability. The mean score of the HOSHRA index among the selected hospitals was 71.53 ± 5.93, indicating that the risk of OSH was at a moderate level. The highest and the lowest risk levels, according to the developed HOSHRA index, were 65.86 ± 8.28 and 75.48 ± 5.66 for ergonomic and biological hazards, respectively.

The AHP results also revealed that based on the panelists’ point of view, the maximum and minimum weighted coefficients for different hazard categories in
hospitals belonged to biological and physical hazards, respectively. It is noteworthy that the most important items in the biological hazard checklist contributing to these findings were mainly related to the use of automatic in-

Figure 1. The HOSHRA index summary form
Table 2. Results of Validity and Reliability Assessments for the HAZID Checklists of the HOSHRA Index

| Hazard Category   | Number of Items | Cronbach’s Alpha Coefficient | CVI | ICC |
|-------------------|-----------------|-----------------------------|-----|-----|
| Physical          |                 |                             |     |     |
| Electrical shock  | 17              | 0.83                        | 0.91| 0.97|
| Fire and explosion| 27              | 0.74                        | 0.73| 0.99|
| Fall and slip     | 21              | 0.89                        | 0.93| 0.97|
| Radiation         | 17              | 0.76                        | 0.76| 0.95|
| Chemical          | 20              | 0.71                        | 0.84| 0.97|
| Biological        | 29              | 0.73                        | 0.92| 0.99|
| Ergonomic         | 26              | 0.81                        | 0.89| 0.99|
| Psychological     | 26              | 0.72                        | 0.83| 0.98|
| Total (HOSHRA)    | 183             | 0.77                        | 0.85| 0.99|

Figure 2. Intra-category AHP weighted coefficient for physical hazard subcategories and inter-category AHP weighted coefficient for the HOSHRA index

Table 3. Results of the HOSHRA Index in the Studied Hospitals

| Category           | The HOSHRA Index |
|--------------------|------------------|
|                    | Mean ± SD        | Maximum | Minimum |
| Physical hazards   |                  |         |         |
| Electrical shock   | 60.6 ± 11.16     | 75      | 40      |
| Fire and explosion | 63.2 ± 10.04     | 80      | 43      |
| Fall and slip      | 77.9 ± 6.88      | 88      | 71      |
| Radiation          | 79.5 ± 6.85      | 90      | 70      |
| Total              | 74.39 ± 5.53     | 80.4    | 66.5    |
| Chemical hazards   | 69.87 ± 6.07     | 80      | 62.5    |
| Biological hazards | 75.48 ± 5.66     | 85.8    | 68.3    |
| Ergonomic hazards  | 65.86 ± 8.28     | 78.6    | 53.7    |
| Psychological hazards | 70.81 ± 10.97 | 87.2    | 54.5    |

Interestingly, the AHP weight for ergonomic and psychological hazards was higher than that of chemical and physical ones. The items of the checklists contributing to such results were mainly associated with the lack of access to adjustable tables, being involved in static tasks such as long-term standing jobs, and distracting noises for er-
gonomic hazards. Lack of kindergartens, limited break time, and shift work were also considered as psychological hazards. In a study on occupational hazards in the Thai healthcare sector, it was similarly revealed that after biological hazards, musculoskeletal and psychological problems were the most prevalent problems among HCWs. Other factors, such as long shift work and lack of required HCWs were also taken into account as the reasons for such findings (3).

The highest value of the AHP weighted coefficient among the main hazard categories belonged to biological ones (\( w = 0.34 \)), denoting that the experts believed that biological hazards among hazard categories were more likely to make occupational problems for HCWs. In a study performed in Greece, both HCWs and experts assigned high and moderate risks to biological hazards (37).

Among hazard categories in the HOSHRA index, the minimum value of the HOSHRA index (i.e., the highest level of OSH risk) belonged to ergonomic hazards (65.86 ± 8.28), suggesting a high level of OSH risk in the studied hospitals. The main reasons regarding such findings were related to a lack of adequate knowledge among HCWs of work postures and patient handling and mobility. Similarly, the perception of occupational hazards in Greek HCWs was examined, and a risk assessment matrix was developed after preparing general questionnaires and completing them by experts and HCWs in hospitals, through which the perception of experts and personnel in different hazard categories were compared. The perceptions were found different when assessing management and ergonomic categories, as the experts believed that the risk of these categories was high, but HCWs perceived them as a moderate risk. Such discrepancies in concepts happen as experts might have more information about appropriate postures and patient handling and mobility compared with general HCWs (37).

In the category of physical hazards, the maximum AHP weighted coefficient was associated with fall and slip. However, the risk of fall and slip in the selected hospitals were categorized at a high level. These findings were in accordance with those of the studies by Bell et al., and Raeissi et al., in which the percentage of HCWs encountering falls and slips were one of the highest ones in a selected Iranian hospital (38). Moreover, according to the United States Bureau of Labor Statistics in 2007, the incidence of slipping and falling injuries in hospitals was 35 per 10,000 HCWs (39). These findings indicated the necessity of a preventative program to manage the fall and slip risks in healthcare centers (2).

The risk of the electrical hazard was categorized as a high-level one. In other words, electrical hazard had the highest value in the HOSHRA index in all categories and subcategories. The main reasons for the items in the checklist were related to lack of building wiring map, absence of protective switches, and lack of using protective equipment against electrical hazards by HCWs involved in this hazard category. In the studied hospitals, the lowest OSH risk level in the physical subcategory belonged to the radiation hazard since there was a strict rule by law enforcement agencies, including the Atomic Energy Agency concerning radiation protection. Furthermore, health physicists could oversee the proper observance of radiation protection rules and regulations in hospitals. HCWs had a good risk perception about radiation, and they took it seriously. In a study performed in a hospital in Iran, random exposure to radiation was also reported by nearly half of HCWs (38). Greek HCWs in a study by Tziaferi et al., ranked radiation hazard as a high-risk agent in the studied hospitals, although the experts believed that it could be grouped in the moderate risk category (37).

Totally, according to the mean score of the HOSHRA index in the selected hospitals, all of these hospitals were categorized at a moderate level. One of the reasons for a low standard deviation (SD) in the current study was probably because all the studied hospitals were affiliated to the same university, and they followed a similar OSH policy. In addition, the developed index was applied only in 36 teaching hospitals in a cross-sectional study. On the other hand, there was no significant correlation between the HOSHRA index and occupational injuries and diseases, since not all the required data were documented appropriately in the studied hospitals and the number of hospitals was inadequate for this purpose. Therefore, more longitudinal studies with larger sample sizes in various periods should be included to find out whether the developed index would be correlated in all subcategories with data on accidents and occupational diseases.

5.1. Conclusion

The developed observation-based method showed an acceptable content validity and reliability for OSH risk assessment of hospitals. The HOSHRA index could also be applied to hospitals as an applicable measure to improve their OSH. In general, the risk of OSH among the studied hospitals was evaluated as moderate.

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Footnotes

Authors’ Contribution: Study concept and design: M. J. and A.M; data collection: A. M. and F.ZD; analysis and interpretation of data: M. J., A.M, and F.ZD; drafting of the manuscript: A. M. and F.ZD; critical revision of the manuscript for important intellectual content: M. J., A. Ch., and M. Sh.; statistical analysis: H. T.

Conflict of Interests: The authors declared no conflict of interest.

Ethical Approval: The study was reviewed and approved by the Vice-Chancellor Office for Research Affairs at Shiraz University of Medical Sciences, Shiraz, Iran. All hospital administrators agreed to assess OSH risks in their hospitals.

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