Vol.19, No.4, Page 266- 281, 2025 http://dx.doi.org/10.59628/jchm.v19i4.2084 ISSN 2958-7476 JMCH

Sana'a University Journal of Medical and Health Sciences

Assessment of the Performance of Healthcare Providers in the Expanded Programme of Immunization Before and After an Educational Intervention, Sa'adah, Yemen, 2025.

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Abstract

Background: After achieving high vaccination coverage, vaccine failure may occur. Sufficient knowledge, practices, and safety practices of workers in the expanded immunization program are factors that affect the prevention of this failure.
M***ethod:*** This quasi-experiment was conducted to assess the knowledge and practices of HCWs involved in the EPI, as well as their safety practices, before and after an educational intervention in Sa'adah, Yemen, in 2025. The study included 26 HCWs from 26 health facilities in 11 districts of the Sa'adah Governorate, Yemen. Data were collected through field visits to hospitals and health centers in the targeted districts between January 1 and January 20, 2025, to collect the data required for the pre-intervention knowledge, practice, and safety practice questionnaires. The second phase, four months after the intervention, from May 3 to May 13, 2025, collected post-intervention data. Data were analyzed using SPSS version 26.
Results: HCP knowledge scores improved after the educational intervention, from 26.9% 'good' to 65.4%. HCP practices improved, with correct practices increasing from 76.9% to 92.3% (p = 0.015). Injection safety practices did not significantly improve. General secure safety practices increased from 26.9% to 92.3% for good practices after the intervention; the statistical significance was marginal (p=0.063).
Conclusion: Educational intervention programs in Sa'adah, Yemen, effectively improved healthcare providers' immunization knowledge and practical skills.

Article Info

Keywords:
knowledge, Expanded programs on immunization, Sa'adah, Yemen, 2019, 2025.

Article History:
Received: 23-July-2025,
Revised: 30-July-2025,
Accepted: 9-August-2025,
Available online: 31-August-2025.

1. INTRODUCTION

The Expanded Program on Immunization (EPI) was launched by the World Health Organization in 1974 to provide universal access to vaccines. It originally targeted six major diseases, and its core components included program management, delivering vaccinations, disease surveillance and control, vaccine supply and cold chain management, advocating vaccine acceptance, training and supervising healthcare workers, and managing data. Over time, the programme has expanded to include additional vaccines, such as HPV, and its approach has contributed to a significant reduction in child mortality.[1, 2]

Immunization, particularly vaccination, plays a vital role in establishing immunity or resistance to infectious diseases. Vaccines provide protection against infections and subsequent diseases [2]. Immunization can be achieved through active or passive means, whether from natural or artificial sources. Natural

sources involve exposure to the environment, animals, and humans, whereas artificial sources result from medical interventions [3].

The cold chain system of the Expanded Programme on Immunization (EPI) is a temperature-controlled supply chain that maintains vaccines at an optimal temperature of +2 to +8℃ from manufacturing until administration to ensure their efficacy and safety. It involves maintaining vaccines within this strict temperature range throughout storage, transport, and vaccination sessions. The system's success relies on three critical elements: trained personnel responsible for operating and maintaining the equipment and handling vaccines; appropriate equipment such as refrigerators, cold boxes, and temperature monitoring devices; and well-defined procedures for managing vaccine distribution and use. Proper implementation of these components ensures that vaccines do not lose potency due to heat exposure or freezing, which would render immunization ineffective. Maintaining an unbroken cold chain between the manufacturer and the patient is essential for effective immunization programs worldwide[4, 5, 6].

The knowledge and practices of HCWs involved in EPI are essential for the success of immunization efforts worldwide. HCWs are tasked with administering vaccines, ensuring that the cold chain is maintained, managing Adverse Events Following Immunization (AEFIs), and engaging communities to encourage vaccine acceptance. Research has demonstrated that healthcare workers' comprehension of immunization guidelines significantly influences vaccination coverage and program effectiveness[7].

A cross-sectional study in Pakistan found that over 50% of vaccinators lacked formal EPI training, with only 45% correctly identifying the immunization schedule, although attitudes toward the national immunization program were generally positive[8, 9]. Similarly, in Thailand, only 55.6% of healthcare workers (HCWs) correctly answered questions on the immunization schedule for schoolchildren, with those receiving adequate training showing significantly better knowledge ($p < 0.001$) [10]. Continuous education and supervision have been emphasized, especially in remote health centers. In Italy, 57.3% of HCWs considered vaccine information reliable; however, only 14.1% knew all recommended vaccinations for HCWs, highlighting the need for ongoing training [11]. An Indian study showed that while 85% of HCWs believed in vaccine efficacy, only 40% felt confident discussing vaccines with parents because of outdated information, underscoring the importance of equipping HCWs to communicate effectively with caregivers [12].

Improper vaccine storage practices and poor knowledge of cold chain management affect the quality of administered vaccines [13], and high knowledge and positive attitudes increase the implementation of cold chain management[14]. HCWs must have sufficient knowledge to manage cold chains [15]. Various studies have revealed that different factors influence the level of knowledge of cold chain management, such as Age and Location of Practice[16]. Profession. work experience and receiving EPI training [17, 18, 19].

EPI emphasizes safety practices to ensure the effective and safe delivery of vaccines. These practices include the use of sterile equipment, proper disposal of sharps, and adherence to cold-chain management to maintain vaccine potency[20, 21]. Additionally, training and education of vaccinators are crucial for enhancing knowledge and practices related to immunization safety[8]. In general, safety protocols in the workplace, including those related to immunization programs, often involve the use of PPE and adherence to safety policies that are clear, brief, and accessible to all employees[22, 23].

A cross-sectional study among registered vaccinators in Islamabad and Rawalpindi, Pakistan, showed that 91.4% properly disposed of needles and syringes in safety boxes, and 69.4% opened vaccine refrigerators fewer than twice daily, indicating generally good practice in vaccine handling [8]. In contrast, a study in Northwest Ethiopia revealed suboptimal vaccine safety practices related to the cold chain system, vaccine administration, and waste management, identifying multiple barriers, including storage, delivery, communication, monitoring, and resource challenges [24]. A 2014 mathematical modeling study estimated a significant global disease burden from unsafe injections, attributing numerous annual HBV, HCV, and HIV infections to these practices [25]. These findings highlight the critical need to improve vaccine safety practices, cold chain management, and waste disposal to reduce health risks and improve the effectiveness of immunization programs.

In Yemen, 1970, no vaccinations were available and no immunization program existed before, 1970-1976 only smallpox vaccine for all age groups, 1977s establishment of EPI with the goal of achieving 90% coverage for OPV3, DPT3, and measles and 80% coverage for hepatitis B3 before the age of 12 months by the end of 2005. The recommended vaccination schedule includes vaccines against tuberculosis, poliomyelitis, measles, diphtheria, pertussis, hepatitis B, and diseases caused by Haemophilus influenzae, 1979Yemen was declared free from smallpox[26]. In 1982, UNICEF launched Child Survival and Development, which included immunization, along with other cost-effective,

high-impact interventions[27]. In 1998, the hepatitis B vaccine was introduced, and in June 2009, Yemen was declared polio-free, the 2011Pneumococcal vaccine was introduced, the rotavirus vaccine (Rota) was introduced in 2012, the 2015 Rubella vaccine and the Inactivated Polio vaccine(IPV) were introduced, making 12 vaccines for children and one for women[5].

In Saadah governorate during the period from January to December 2020, a total of 114 cases of acute flaccid paralysis (AFP) were reported from 87% (13/15) of districts, and vaccine-derived poliovirus type 1 (cVDPV1) was confirmed in 26% (30) of the AFP cases. 75% (21) were < 5 years old, and 73% (20) had zero doses of Oral Polio Vaccine (OPV[28].

This study aimed to evaluate the knowledge, practice, and safety practices of HCWs who work in EPI in Sa'adah governorate, Republic of Yemen, before and after educational intervention.

2. METHODS

2.1. STUDY AREA

The study was conducted in 26 health facilities of the districts in Sa'adah Governorate, North Yemen, Republic of Yemen, 11 out of 15 districts in which the study was conducted, two urban districts (Sa'adah and Sahar), which contain 17 health facilities, and nine rural districts (As Safra, Baqim, Ghamr, Haydan, Majz, Monabbih, Qatabir, Razih, and Saqayn), which contain 9 health facilities.

2.2. Time of study

The study was conducted in the time frame from the period from January 1 to May 13, 2025.

2.3. Study design

A quasi-experiment was conducted before and after the educational intervention.

2.4. Study population and centers

Health care personnel working in EPI

2.5. Data Collection Tools and Procedures

An appropriate pre-tested questionnaire was used to collect data from HCWs working in the EPI. This includes the following.

1- Questionnaire for socio-demographic characteristics.

2- **Interviewing questionnaire for assessing the knowledge of HCPs working in EPI** regarding immunization schedule (dose and time), method of BCG and pentavalent administration, time of measles vaccination given, temperatures required for keeping polio and pentavalent vaccines, partially used polio vials (opened), and shake tests.

3- **An observation checklist for assessment of practices of HCPs Working in EPI** used for assessment of general practices of healthcare personnel involved in EPI was focused on handling the syringes, cleaning the injection area, direction of the needle for pentavalent and measles vaccination, reconstitution of the vaccine, and way of keeping the vaccines during the sessions.

4- ***An observation checklist for assessment of safety practices of HCPs working in EPI*** about the types of injection equipment used for routine immunization, handling the syringes, presence of a national system for monitoring adverse event(s) following immunization (AEFI), distribution of safety boxes with all vaccine deliveries, policies regarding methods of sharp disposal, and vaccine administration methods for different vaccines.

Main Outcome Variable Measurement.

The answers to each question were scored as follows:

1- Score "1" for correct.
2- Score "0" for incorrect.

Summation of knowledge answer scores was done. Then, the percentage total score was calculated. The total sum of the knowledge was graded as follows:

- Good $\geq$ 75%
- Fair 51%-74 %
- wrong $\leq$ 50 %

The answers to each practice question were scored as follows.

1- Score 1 for safe/correct practice or presence of safe conditions
2- Score 0 for unsafe/incorrect practice or unsafe conditions.

A summation of the practice answer scores was performed. Then a percent total score was calculated. The total sum of practice was graded as follows:

- Good practice: Score $\geq$ 70%
- Satisfactory practice: Score 50% to <70%
- Poor practice: Score < 50%

2.6. The setting, implementation, and evaluation of an educational intervention programme in the year 2025.

- To fulfil the general objective of this study, the researcher developed a mini-guide derived from the

Health Worker Guide for the EPI in the Republic of Yemen. The results informed the creation of this guide, which draws on a previous assessment of health workers participating in the Expanded Program on Immunization. The assessment was conducted by a researcher in 2019.

Following the initial evaluation, a WhatsApp group was set up to facilitate feedback and continuous learning for health workers. The group disseminated the assessment results, shared best practices, and addressed questions about immunization. All 26 health workers involved in the evaluation were invited to participate in the study. Based on the results, the participants were informed of their weaknesses and performance gaps. Targeted recommendations and missing information were communicated and discussed in the group to promote problem solving, knowledge retention, and competency enhancement.

Four months after the training, booklet distribution, and continuous learning through the WhatsApp group, a follow-up evaluation was performed. The same questionnaire was used to assess the impact of the intervention program on health workers in the EPI.

2.7. Data collection

Data were collected through field visits to hospitals and health centers in the targeted districts within a two-period period first before intervention from January 1 to January 20, 2025, secund after intervention from May 1 to May 13, 2025, to investigate all the data required in the questionnaires mentioned above, and to interview the health workers in the EPI to fill the questionnaire on HCWs' knowledge.

2.8. Ethical CONSIDERATION

The Ethics Committee of the Faculty of Medicine, Sana'a University approved the study in January 2025, and an official letter was obtained and addressed to the Director General of the Health and Environment Office, Sa'adah Governorate.

2.9. Data Analysis

Statistical analysis was performed using the data analysis software Statistical Package for the Social Sciences **(SPSS)** version 26. Statistical significance was set at $p < 0.05$. Differences in sample means were evaluated using the chi-squared test. McNemar's test and Fisher's exact test were used for assessment.

3. RESULT

3.1. Socio-demographic characteristics of HCPs

Table[1] revealed that Most healthcare professionals were women aged 35– 44, primarily working in rural areas, with midwives being the largest group. Nearly half had secondary education, and work experience averaged 12.5 years. Most participants had training in immunization and cold chain management, although some lacked training. Just over half had emergency vaccine management protocols, and vaccine inventory management was well-maintained in over 90% of the facilities.

3.2. Comparison of Knowledge of HCP target group working in EPI subjected to educational program before and after educational intervention program in (Sa'adah, Yemen, 2025)

Table [2] showed the comparison of healthcare providers' knowledge before and after the educational intervention program in Sa'adah, Yemen, demonstrating significant improvements in several key areas related to vaccine handling and adverse event management. Notably, the correct understanding of the purpose of DTPaHepB vaccine practice increased markedly from 19.2% before the intervention to 61.5% afterward. Similarly, knowledge of the timing of the measles vaccine improved significantly from 38.5% to 61.5%. The awareness of vaccines most sensitive to heat rose substantially from 30.8% to 80.8%, and the recognition of vaccines sensitive to freezing increased even more dramatically from 8% to 84.6%. Knowledge of the shake test method also showed a significant jump from 3.8% pre-intervention to 50% post-intervention.

However, some knowledge areas remained stable with no significant changes following the intervention. For example, the immunization schedule, dose, and timing, as well as the correct administration methods for BCG and DTPaHepB vaccines, had consistently high correct responses of approximately 80-88% both before and after the program. The timing of measles vaccination already had 100% accuracy prior to the intervention. Other stable areas included refrigerator temperature monitoring frequency and appropriate vaccine storage temperature range, reflecting correct knowledge levels above 75%. Policies on using partially used polio vaccine vials and storage temperatures for DTPaHepB and polio vaccines also remain unchanged.

3.2.1. General scores of knowledge of HCP working in EPI (Sa'adah, Yemen, 2025) before and after the educational intervention program

Table [3] illustrates the general scores of knowledge of HCPs working in the EPI in Sa'adah, Yemen, before and after participation in an educational intervention program. The data showed a marked improvement in knowledge after the intervention. Before the program, only 7 (26.9%) of the participants achieved a "Good" knowledge score, while 11 (42.3%) were classified as "Fair" and 8 (30.8%) as "Poor." After the educational intervention, the proportion of HCPs with a "Good" knowledge score increased substantially to 17 (65.4%), whereas those with "Fair" and "Poor" scores decreased to 5 (16.2%) and 4 (15.4%), respectively. The statistical analysis using the chi-square test revealed a highly significant difference between the pre- and post-intervention distributions (χ^2 = 22.482, p = 0.001), indicating that the educational program had a significant positive impact on the overall knowledge of the participating healthcare providers

storage procedures in place in case of equipment failures or power outages

3.2.2. Relationship between sociodemographic characteristics of HCP working in EPI and knowledge score (Sa'adah, Yemen, 2025)

Table [4] presents the relationship between sociodemographic characteristics of HCPs working in the EPI and their knowledge scores in Sa'adah, Yemen, 2025. The analysis utilized The chi-square test was used to assess the statistical significance of associations between various demographic factors and knowledge levels (categorized as Poor, Fair, and Good).

Among the variables analyzed, age group was the only characteristic significantly linked with knowledge scores (??=0.017). Notably, HCPs aged 24–33 years were more prone to exhibit poor knowledge 5 (19.2%) compared to older HCPs. Conversely, the proportion of HCPs with good knowledge improved as age increased, peaking in the 54+ years age group. This trend indicates that accumulated experience or extended exposure in the field might be positively associated with a better understanding of immunization practices.

Other sociodemographic factors, including sex (p=0.437), residence at the center (urban vs. rural, p=0.868), type of health facility (p=0.420), job title (p=0.574), and educational level (p=0.310), did not show statistically significant associations with knowledge scores. This indicates that within this sample, these variables did not meaningfully differentiate knowledge levels among the HCPs.

3.3. Comparison between practices of HCP working in EPI before and after educational intervention program in (Sa'adah, Yemen, 2025)

Table [5] revealed that educational intervention significantly improved several critical immunization practices among healthcare providers. Notably, the proportion of HCPs who correctly cleaned the injection area using the spiral swab technique increased from 26.9% before the intervention to 42.3% after the intervention (p=0.001). Similarly, the practice of checking for blood by pulling the piston before injection increased significantly from 46.2% to 76.9% (p=0.017). The percentage of providers performing compression at the injection site also improved markedly, from 61.5% to 73.1% (p=0.000). Additionally, the timing of reconstituting freeze-dried vaccines and the use of an icebox to keep vaccine vials cold throughout immunization sessions showed statistically significant enhancements (p=0.000 and p=0.018, respectively).

Although there were improvements in other practices, such as handwashing before handling vaccine vials, which increased from 3.8% to 23.1%, these changes were not statistically significant (p=0.231). Several key practices, including correct injection handling and site location as well as proper oral polio dose administration, were already at high levels before the intervention and remained consistently optimal afterward. Overall, the findings demonstrated that the educational program effectively strengthened essential vaccination practices, with room for further improvement in areas such as hygiene protocols.

3.3.1. Comparison between general score practices of HCP working in EPI before and after educational intervention program in (Sa'adah, Yemen, 2025)

Table [6] illustrates that, before the intervention, 20 (76.9%) of HCPs demonstrated correct practices, which increased significantly to 24 (92.3%) following the program. Hence, the percentage of those with correct but incomplete practices declined from 5 (19.3%) to 2 (7.7%), and those classified as incorrect practices decreased from 1 (3.8%) to zero post-intervention. The differences between pre- and post-intervention were statistically significant (X^2 = 14.733, p = 0.015), illustrating the educational intervention's substantial positive impact on health care providers' overall practices.

3.3.2. Relationship between knowledge and practice score before and after educational intervention (Sa'adah, Yemen, 2025)

Tab [7] revealed the relationship between healthcare providers' knowledge and practice scores before the educational intervention in Sa'adah, Yemen, showed a clear and statistically significant association (^{2} = 2.805, p =

Table 1. Distribution of socio-demographic characteristics of HCP working in EPI (Sa'adah, Yemen, 2025)

Sociodemographic distribution		Frequency (n=26) N%
Age	25-34	7 (26.9)
	35-44	14 (53.8)
	45-54	3 (11.5)
	55-64	2(7.7)
Range		24-60
Mean ± SD		38.69 ± 9.15
Median		38.5
Sex	Male	11 (42.3)
	Female	15 (57.7)
Area of the center	Urban	6 (23.1)
	Rural	20 (76.9)
Type of health facility	Hospital	14 (53.8)
	Health center	12 (46.2)
Job	Nurse	6 (23.1)
	Morshedien	4 (15.4)
	Midwife	10 (38.5)
	Health inspector	6 (23.1)
Educational level	University	9 (34.6)
	Secondary	12 (46.2)
	Preparatory	4 (15.4)
	Primary	1 (3.8)
Work experience in a year	1-10	14 (53.8)
	11-20	6 (23.1)
	21-30	4 (15.4)
	31-40	2 (7.7)
Range	1-34	
Mean ± SD	12.5 ± 9.78	
Median	10	
Special training in EPI and cold chain	Yes	23 (88.5)
	No	3 (11.5)
Number of training courses	Range	0 – 10
	Mean ± SD	4 ± 3.72
When the last training course attended	Range	0 – 7
	Mean ± SD	2.5 ± 1.48
	Median	2.5
Do you have written emergency retrieval and storage procedures in place in case of equipment failures or power outages?	Yes	15 (57.7)
	No	11 (42.3)
Do you keep records of received and stored doses of vaccine (inventory management)	Yes	24 (92.3)
	No	2 (7.7)

0.004). Participants with good or fair knowledge demonstrated high proportions of correct practice, with 85.7% and 81.8%, respectively, practicing appropriately, and none showed wrong practices. In contrast, those with poor knowledge had a significantly lower rate of correct practices (62.5%) and a higher incidence of incomplete or incorrect practices (37.5%). This indicates that higher knowledge levels were strongly linked to better practice behaviors prior to intervention.

After the intervention, the overall proportion of participants demonstrating correct practices remained relatively stable at 76.9%. However, the previously significant association between the knowledge and practice scores disappeared (^{2} = 7.666, p = 0.223). Notably, the rate of correct practice among those with fair knowledge decreased to 60%, and incorrect practice among those with poor knowledge increased to 25%. These findings suggest that while the educational program helped maintain overall good practice levels, it also altered the direct relationship between knowledge and practice. This might

Table 2. Comparison of Knowledge of HCP target group working in EPI subjected to educational program before and after educational intervention program in (Sa'adah, Yemen, 2025)

Item of HCP knowledge	before the educational intervention program (n=26) Frequency %				After an educational intervention program (n=26) frequency %				McNemar P. Valu
	Correct		Incorrect		Correct		Incorrect		
	Frequency	percent	Frequency	percent	Frequency	percent	Frequency	percent	
Immunization schedule, dose, and Time	22	84.6	4	15.4	22	84.6	4	15.4	26.00 1.00
How BCG is administered	23	88.5	3	11.5	23	88.5	3	11.5	26.00 1.00
Why	2	7.7	24	92.3	15	57.7	11	42.3	1.589 0.323
How DTPaHepB is administered	21	80.8	5	19.2	21	80.8	5	19.2	26.00 1.00
Why2	6	19.2	20	80.8	16	61.5	10	38.5	3.86 0.001*
When measles is given	26	100	-	-	26	100	-	-	-
Why3	10	38.5	16	61.5	16	61.5	10	38.5	10.16 0.031*
How many times should the temperature of the refrigerator be monitored and recorded	20	76.9	6	23.1	20	76.9	6	23.1	26.00 1.00
At what temperature range are vaccines generally stored at the health center	22	84.6	4	15.4	22	84.6	4	15.4	26.00 1.00
Which of these vaccines is the most heat-sensitive	8	30.8	18	69.2	21	80.8	5	19.2	0.337 0.001*
Which of these vaccines is most sensitive to freezing	2	8	24	92	22	84.6	4	15.4	0.394 0.0001*
Temp. of keeping DTPaHepB (Penta)	25	96.2	1	3.8	25	96.2	1	3.8	26.00 1.00
Temp. Of keeping polio	25	96.2	1	3.8	25	96.2	1	3.8	26.00 1.00
If a child develops convulsions convulsions after receiving DTPaHepB. What will you do when it's the next time for vaccination	2	7.7	24	92.3	14	53.8	12	46.2	1.857 0.0001*
Will you give frozen DTPaHepB (Penta)	24	92.3	2	7.7	24	92.3	2	7.7	26.00 1.00
Why4	15	57.7	11	42.3	18	69.2	8	30.8	15.758 0.250
Partially used polio vial (open).). It could be used the next day	23	88.5	3	11.5	25	96.2	1	3.8	0.136 1.00
Do you know what a shake test is	18	69.2	8	30.8	20	76.9	6	23.1	17.550 0.500
What is the Shake test	1	3.8	25	96.2	13	50	13	50	1.040 0.0001
On which of the following following vaccines can the shake test be carried out	17	65.4	9	34.6	22	84.6	4	15.4	8.929 0.63
**Significant (p<0.05)									

Table 3. General scores of knowledge of HCP working in EPI (Sa'adah, Yemen, 2025) before and after the educational intervention program

General score knowledge:	Before the program (n=26) N %	After the program (n=26) N %	X^2 *P**
Good	7 (26.9)	17 (65.4)	
Fair	11 (42.3)	5 (16.2)	**22.482**
Poor	8 (30.8)	4 (15.4)	**0.001*** **
Total	**26 (100)**	**26 (100)**	

*Chi-Square Tests **P.Value **Significant (p<0.05)

Table 4. Relationship between socio-demographic characteristics of HCP working in EPI and knowledge score (Sa'adah, Yemen, 2025)Score

Knowledge score Item of sociodemographic		Poor (n=8) N %	Fair (n=11) N %	Good (n=7) N %	Test of significance*
Age	**24-33**	5 (71.4)	2 (28.6)	**0** (0.0)	X^2 = 0.017**
	34-43	3 (21.4)	8 (57.2)	3 (21.4)	
	44-53	0 (0.0)	1 (33.3)	2 (66.6)	
	54+	0 (0.0)	0 (0.0)	2 (100.0)	
Sex	**Male**	2(18.2)	5 (45.5)	4 (36.4)	X^2 =0.437
	Female	6 (40.0)	6 (40.0)	3 (20.0)	
Residence of the center	**Urban**	2 (33.3)	2 (33.3)	2 (33.3)	X^2 =0.868
	Rural	6 (30.0)	9 (45.0)	5 (25.0)	
Type of health facility	**Hospital**	3 (21.4)	6 (42.9)	5 (35.7)	X^2 = 0.420
	Health center	5 (41.7)	5 (41.7)	2 (16.7)	
Job	**Midwife**	5 (50.0)	3 (30.0)	2 (20.0)	X^2 = 0.574
	Nurse	2 (33.3)	2 (33.3)	2 (33.3)	
	Health inspector	1 (16.7)	3 (50.0)	2 (33.3)	
	Morshedien	0 (0.0)	3 (11.5)	1 (3.8)	
Educational level	**University**	2 (22.2)	4 (44.4)	3 (33.3)	X^2 = 0.310
	Secondary	6 (50.0)	5 (41.7)	1 (8.3)	
	Preparatory	0 (0.0)	1 (33.3)	2 (66.7)	
	Primary	0 (0.0)	1 (50.0)	1 (50.0)	

*Chi-Square Test **P. Value ***Significant (p<0.05)

Table 5. Comparison between practices of HCPs working in EPI before and after educational intervention program in (Sa'adah, Yemen, 2025)

health care personnel practice		Before program (n=26) N0 %	After program (n=26) N0 %	X^{2*} P**
Washing hands before any manipulation of the vac. Vials	Yes	1 (3.8)	6 (23.1)	3.469 0.231
	No	25 (96.2)	20 (76.9)	
Handling the syringe (touching only safe parts)	Yes	26 (100)	26 (100)	-
No used needles are retained in the vaccine vial	Yes	26 (100)	26 (100)	-
Clean area with swab corrects (spiral)	Yes	7 (26.9)	11 (42.3)	13.062 0.001***
	No	19 (73.1)	15 (57.7)	
Direction and location of the needle in DTPaHepB (right thigh angle 90)	Yes	26 (100)	26 (100)	-
Direction and location of of the needle in the measles vaccine (45-degree angle of the left forearm bone)	Yes	26 (100)	26 (100)	-
Site of the injection proper	Yes	26 (100)	26 (100)	-
Pull the piston to see blood	Yes	12 (46.2)	20 (76.9)	6.686 0.017***
	No	14 (53.8)	6 (23.1)	
compression at the site of injection	Yes	16 (61.5)	19 (73.1)	15.326 0.000*
	No	10 (38.5)	7 (26.9)	
correct oral polio dose	Yes	26 (100)	26 (100)	-
Time of freeze-dried vaccines reconstitution (if the vaccine administered one of measles, MMR, or BCG).				19.855 0.0001***
At the moment of the arrival of the first child		21 (80.8)	80.8	
At the beginning of the session day		5 (19.2)	19.2	
Presence of an ice box to	Yes	22 (84.6)	24 (92.3)	11.917 0.018***
	No	4 (15.4)	2 (7.7)	
Ice is replaced before it melts completely	Yes	22 (84.6)	21 (80.8)	19.855 0.0001***
	Not Found	4 (15.4)	5 (19.2)	

*Chi-Square Test **P. Value ***Significant ($p<0.05$)

Table 6. General scores of practices of HCPs working in EPI (Sa'adah, Yemen, 2025) before and after the educational intervention program

General score practice	Before program (n=26) No %	After program (n=26) No %	X^{2*} P**
Correct practice	20 (76.9)	24 (92.3)	
Correct but not complete practice	5 (19.3)	2 (7.7)	**14.733**
Wrong Practice	1 (3.8)	0 (0.0)	**0.015*** **
Total	26 (100.0)	26 (100.0)	

*Chi-Square Test **P. Value ***Significant (p<0.05)

indicate that the intervention improved practical skills or motivation, enabling participants with lower knowledge levels to perform better despite their knowledge deficits.

3.4. Comparison of safety practices of EPI through injection safety in Sa'adah, Yemen, 2025, before and after the educational intervention program.

The table [8] reveals that for most items, there was minimal to no change in practices following the educational intervention, and no statistically significant changes were observed. For instance, the proportion of providers who had received injection safety training within the last two years remained constant at 20 (76.9%), both pre- and post-intervention (^{2} = 26.000, p = 1.000). Additionally, the use of auto-disabled syringes was already universal 26 (100%) for both before and after intervention, and only 1 (3.8%) of syringes or needles was reported post-intervention, with only a small change from 23 (88.5%) to 25 (96.2%) with (p=0.500). The practice of recapping syringes decreased from 5 (19.2%) to 2 (7.7%), and the proportion of providers who placed syringes directly into safety boxes increased from 20 (76.9%) to 24 (92.3%). However, these improvements were not statistically significant (recapping, ^{2} = 9.100, p = 0.250; direct disposal, ^{2} = 7.222, p = 0.125).

Other indicators, such as the presence of a national system for monitoring adverse events following immunization and the distribution of safety boxes, also showed no significant changes, with high compliance rates maintained throughout the study period. The presence of dirty or improperly stored swabs increased from 18 (69.2%) to 22 (84.6%), with no statistically significant difference (^{2} = 10.636, p = 0.125). The presence of overflowing or open sharp boxes and evidence of sharps used around the facility exhibited minimal or no improvement, and none of these changes reached statistical significance (e.g., evidence of used sharps: ^{2} = 18.489, p = 0.500).

3.4.1. Comparison between general score safety practices of HCP working in EPI before and after educational intervention program in (Sa'adah, Yemen, 2025)

The table [9]presented that an educational intervention improved the safety practices of HCPs in the EPI program in Sa'adah, Yemen. Before the intervention, only about a quarter 7 (26.9%) of the providers showed good safety practices, but post-intervention, the majority 24 (92.3%) of providers showed good safety practices. The observed change was just above the conventional threshold for statistical significance (p=0.063).

4. DISCUSSION

4.1. Knowledge of HCP working in EPI before and after educational intervention program in (Sa'adah, Yemen, 2025)

The present study demonstrated that the educational program significantly improved healthcare providers' (HCPs) knowledge in key areas. Understanding of the reason for the DTPaHepB vaccine practice increased by 3.2-fold, from 6 (19.2%) to 16 (61.5%) post-intervention (^{2} = 3.86, p = 0.001). Similarly, knowledge of the timing of the measles vaccine increased by 1.7-fold, from 10 (38.5%) to 16 (61.5%) (^{2} = 10.16, p = 0.031). These results are consistent with findings from Qatar, where immunization education programs significantly enhance nurses' knowledge [29], and with those of Uskun et al. (2007), who reported marked post-training improvements among primary healthcare workers [30].

Improvements were also observed in the knowledge of cold chain management and vaccine sensitivity. Correct responses regarding the most heat-sensitive vaccines increased 2.6-fold (8 [30.8%] to 21 [80.8%], ^{2} = 0.337, p = 0.001), and knowledge of freeze-sensitive vaccines

Table 7. Relationship between knowledge and practice score before and after educational intervention (Sa'adah, Yemen, 2025)

	Practice score	Good	Fair	Poor	Total
	Knowledge score	No %	**No %**	**No %**	**No %**
BEFORE	**Correct practice**	6 (85.70)	9 (81.80)	5 (62.50)	20 (76.9)
	Correct but not complete practice	1 (14.30)	2 (18.20)	2 (25.00)	5 (19.3)
	Wrong Practice	0 (0.00)	0 (0.00)	1 (12.50)	1 (3.8)
	Total	7 (26.9)	11(42.3)	8 (30.8)	26 (100.0)
	X * P**			**2.805 0.004*****	
AFTER	**Correct practice**	14 82.40()	3 (60.0)	3 (75.0)	24 (92.3)
	Correct but not complete practice	3 (17.60)	2 (40.0)	0 (0.00)	2 (7.7)
	Wrong Practice	0 (0.00)	0 (0.00)	1 (25.0)	0 (0.001)
	Total	17 (65.4)	5 (16.2)	4 (15.4)	26 (100.0)
	X P		**7.666 0.223**		

*Chi-Square Test **P. Value ***Significant (p<0.05)

increased 10.6-fold (2 [8%] to 22 [84.6%], ² = 0.394, p < 0.001). These findings align with prior research identifying cold chain management as a key knowledge gap that significantly improves following targeted educational intervention [29, 30]. The correct knowledge of the shake test also rose dramaticallyby 13-fold from 3.5% to 50% post-intervention, demonstrating a highly significant association. This finding is consistent with Mohammed et al. (2021), who found that training on cold chain management was statistically associated with improved knowledge, and with Ergetie et al. (2023), who showed that higher education, experience, and training were positively correlated with vaccine cold chain knowledge[18, 31].

The present study assessed the knowledge levels of HCPs working in the EPI program in Sa'adah, Yemen (2025), and found that good knowledge scores increased 2.4 times post-intervention, while fair and poor scores decreased by 2.2 and 2 times, respectively. This improvement aligns with the findings of a study in southwestern Nigeria, where training significantly enhanced immunization providers' knowledge and self-reported practices (F = 8.235, P < 0.001)[32]. Similarly, targeted training in Turkey has led to a significant increase in knowledge among primary healthcare workers (P < 0.01)[30]. Additionally, research in Kalasin, Thailand demonstrated a significant knowledge difference between trained and untrained healthcare workers (P < 0.01), further supporting the positive effect of educational interventions on immunization knowledge and practices[10].

This study examined the relationship between sociodemographic characteristics and knowledge scores among HCPs. Age was the only factor significantly associated with knowledge scores (p = 0.017), with older HCPs (44 years and above) more likely to have good knowledge, and none in the youngest group (24–33 years) achieved a "good" score, while 7.7

Regarding sex, male HCPs had slightly higher good knowledge rates (4 [2%]) than females (3 [6%]), but this difference was not statistically significant (p = 0.437). Similar findings have been reported in Pakistan and Nigeria, where male predominance existed without significant knowledge differences by sex[16].

4.2. Practices of HCP working in EPI before and after the educational intervention program in (Sa'adah, Yemen, 2025)

Educational interventions significantly improved key immunization practices among healthcare personnel. Notable improvements included a 1.6-fold increase in the use of spiral motion to clean the injection site (p=0.001), an increased practice of pulling the piston to check for blood before injection by 1.7-fold (p=0.017), and better compression at the injection site (from 61.5% to 73.1%, p<0.001). Additional gains were observed in the timely reconstitution of freeze-dried vaccines (p<0.001), replacement of ice in vaccine carriers before melting (p<0.001), and availability of an icebox to keep vaccines cold (from 84.6% to 92.3%, p=0.018). These results

Table 8. Comparison between different items used for injection safety practice in the EPI (Sa'adah, Yemen, 2025), before and after educational intervention program

socio-demographic distribution:		Before the educational Programme No= 26	After the educational Programme No= 26	X^{2*} P**
Had injection safety training within the last two years	Yes	20 (76.9)	20 (76.9)	26.00
	No	6 (23.1)	6 (32.1)	1.000
Reuse of syringes or needles in this facility, either for immunization or curative injections	Yes	3 (11.5)	1 (3.8)	0.500
	No	23 (88.5)	25 (96.2)	
Type of syringes	Auto-disable	26 (100.0)	26 (100.0)	-
Recapping the syringe after use	Yes	5 (19.2)	2 (7.7)	9.100
	No	21 (80.8)	24 (92.3)	0.250
Put the syringe directly into the safety boxes	Yes	20 (76.9)	24 (92.3)	7.222
	No	6 (23.1)	2 (7.7)	0.125
Presence of a national system for monitoring adverse events following immunization	Yes	3 (11.5)	3 (11.5)	10.097
	No	23 (88.5)	23 (88.5)	1.000
Distribution of safety boxes with all vaccine deliveries (1/100)	Yes	25 (96.2)	25 (96.2)	26.00***
	No	1 (3.8)	1 (3.8)	1.000
Presence of swabs used for skin preparation that are dirty, bloodstained, or kept wet	Yes	18 (69.2)	22 (84.6)	10.636
	No	8 (30.8)	4 (15.4)	0.125
Presence of safety boxes in areas where injections are given	Yes	25 (96.2)	25 (96.2)	26.00***
	No	1 (3.8)	1.(3.8)	1.000
Presence of overflowing, pierced, or open sharp box(es)	No	25 (96.2)	25 (96.2)	26.00***
	Yes	1 (3.8)	1 (3.8)	1.000
Sharps in plastic bottles or open containers expose staff to needle-stick injuries.	No	26 (100.0)	26 (100.0)	-
Evidence of used used sharps around the health center and/or the disposal site	Yes	10 (38.5)	8 (30.8)	18.489
	No	16 (61.5)	18 (69.2)	0.500
Type of waste disposal facility used for the disposal of the majority of sharps	Incinerator	25 (96.2)	25 (96.2)	-
	Open burning on the ground	1 (3.8)	1 (3.8)	

* McNamar Test **P. Value ***Change in one variable to show comparison

Table 9. General scores of safety practices of HCPs working in EPI (Sa'adah, Yemen, 2025) before and after the educational intervention program

General score of safety practice	Before program (n=26) No %	After program (n=26) No %	X^{2*} P**
Good	7 (26.9)	24 (92.3)	**5.881 0.063***
Satisfactory	19 (73.1)	2 (7.7)	
Total	26 (100.0)	26 (100.0)	

* McNamar Test **P. Value

demonstrate improved adherence to post-training safe immunization protocols.

These findings align with those from southwestern Nigeria, where training interventions significantly enhanced knowledge and self-reported immunization practices, which was attributed in part to multisensory teaching methods[32]. Similar significant improvements following targeted training have been reported by Uskun et al. ($p<0.01$) [30]. Reviews of pre-service immunization training in multiple countries also revealed that educational programs improve health workers' knowledge, attitudes, and readiness for immunization[30]. Capacity-building initiatives in Ghana employing various teaching methods likewise enhanced healthcare workers' immunization-related knowledge, attitudes, and practices[33]. A systematic review in Europe emphasized that ongoing tailored education is critical for improving healthcare workers' knowledge, attitudes, and vaccine uptake[34].

Collectively, these individual studies and reviews, including the Yemen intervention, demonstrate that well-structured education strengthens practical skills such as vaccine administration, injection techniques, and cold chain maintenance[16, 33, 35]. However, sustaining these improvements requires continuous refresher training and supervision, given evidence that knowledge and practice gains may decline over time without ongoing education[33, 34].

The general practice scores of HCPs in the EPI program in Sa'adah, Yemen significantly improved following the educational intervention. The correct practice rates increased from 76.9% before the intervention to 92.3% after the intervention ($p = 0.015$). In addition, the proportion of correct but incomplete practices decreased from 19.3% to 7.7%, and incorrect practices were fully eliminated (from 3.8% to 0%). These results indicate that training effectively enhanced the overall quality of immunization practices among the HCPs.

This finding aligns with those of other studies demonstrating the positive impact of educational interventions on healthcare workers' immunization practices. Brown et al. reported significant improvements in self-reported immunization knowledge and practices among primary healthcare providers in Nigeria post training [32]. Similarly, Uskun et al. found that targeted training significantly increased immunization knowledge and practice among healthcare workers ($p < 0.01$)[30]. Systematic reviews further support the idea that multicomponent educational strategies improve vaccine handling, injection techniques, and cold chain management across various settings[30]. However, these studies also emphasize the importance of continuous refresher courses to sustain long-term improvements[30, 32].

4.3. Comparison between different items used for injection safety practice in the EPI (Sa'adah, Yemen, 2025)

Injection safety is a critical element of immunization programs, particularly in low-resource settings such as Sa'adah and Yemen, where unsafe practices, such as syringe reuse and improper disposal, increase the risk of bloodborne infections[36]. Educational interventions have been shown to improve healthcare workers' knowledge and reduce unsafe behaviors such as needle recapping and syringe reuse[37].

The study found that 76.9% of HCPs had received injection safety training within the past two years, remaining stable pre- and post-intervention. Importantly, syringe and needle reuse decreased markedly, from 11.5% to 3.8%, demonstrating the effectiveness of the intervention in reducing this high-risk practice. Syringe recapping rates also declined from 19.2% to 7.7%, although this change was not statistically significant (p=0.250), mirroring previous findings in Yemen and other countries where recapping remains a persistent issue[36, 38]. Nonetheless, educational programs have been effective in improving safety knowledge and practices, as evidenced

by high knowledge and practice levels among nursing students following targeted training[39].

Improvements in waste management were noted, with syringes correctly disposed into safety containers rising from 76.9% to 92.3% (p=0.125), and a reduction in overflowing sharp containers, achieving 100% compliance post-intervention. No pierced sharps containers were observed, consistent with the WHO and CDC guidelines on timely sharps container replacement to minimize occupational risks[40, 41]. However, the use of sharps around health centers indicates ongoing challenges in safe disposal, reflecting broader issues in Yemen's medical waste management despite progress, such as the installation of 60 waste treatment units and improved compliance[42].

Overall, the study showed a substantial increase in 'good' safety practice scores among healthcare workers, from 26.9% before to 92.3% after training (p=0.063). This supports extensive evidence that patient safety education enhances healthcare worker behavior. Systematic reviews and studies have confirmed that repeated multifaceted educational interventions, including mentoring and interactive learning, substantially improve the safety culture and adherence to safety protocols[43, 44]. Additionally, targeted training has been shown to markedly increases compliance with personal protective equipment use in clinical settings[45].

The lack of statistically significant differences between injection safety practices before and after an educational intervention is primarily due to the already high baseline adherence to many practices, such as injection safety training, use of auto-disabled syringes, safe disposal of syringes in safety boxes, and proper waste disposal methods. The initial performance was already very high (close to or at 100%) before the intervention, the small sample size (n=26) limited the power to detect changes, and some practices showed no actual change. This suggests that while some numerical improvements occurred, they were not sufficiently robust, given the pre-existing high performance levels.

5. CONCLUSIONS

Overall, the educational intervention effectively enhanced healthcare providers' knowledge of the critical aspects of vaccine safety, storage, and adverse event management, where initial knowledge gaps existed. Areas with high baseline knowledge showed little to no improvement, likely due to a ceiling effect. These outcomes underscore the value of targeted training programs in addressing specific deficiencies and reinforcing existing knowledge among healthcare workers.

The findings of this study suggest that while certain technical skills have been well established, educational initiatives should prioritize domains that demonstrate greater potential for enhancement.

The findings of these studies collectively reinforce the hypothesis that structured educational programs can effectively enhance safety practices, as evidenced in this study.

6. RECOMMENDATIONS

Key recommendations include targeting ongoing training to address specific knowledge and practice gaps, particularly in infection prevention such as handwashing and managing adverse events, giving special focus to younger, less experienced healthcare providers who tend to have lower knowledge levels, combining theoretical and practical training to ensure lasting improvements, regularly monitoring and evaluating knowledge and practices to identify emerging gaps, and addressing infrastructure challenges to better support infection prevention efforts.

7. ACKNOWLEDGEMENT

We sincerely thank God for His guidance and support. We appreciate the cooperation of the Director General of the Health and Environment Office in Saadah Governorate and the dedicated health workers of the EPI, and extend heartfelt gratitude to my dear wife for her constant support.

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