Knowledge of Pharmacists about Nuclear Pharmacy Services in Saudi Arabia

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ABSTRACT

Goal: The knowledge of nuclear pharmacy is essential in pharmacy practice. In addition, the nuclear pharmacy services demand various diagnoses and drug therapy management. In this study, we aimed to explore pharmacists' knowledge about nuclear pharmacy in the Kingdom of Saudi Arabia. **Methods:** This is a cross-sectional qualitative study. In this study, we distributed an electronic validated reliability questionnaire to all pharmacists and pharmacy interns. Students were excluded from this study. The survey collected demographic data of the responders and the knowledge of pharmacists about nuclear pharmacy, radioactive drugs, and resources of nuclear pharmacy. Data were analyzed using Statistical Package of Social Science (SPSS), Microsoft Excel, and Survey Monkey system. **Results:** A total of 235 pharmacists responded to the survey questionnaire. Of them, 142 (63.96%) were male, and 80 (36.04%) were female, with a statistically significant difference between them ($p<0.001$). About two-thirds of the pharmacists had earned a Bachelor's degree (149 (63.40%)) and Diploma in Pharmacy (75 (31.91%)), with statistically significant differences among all qualifications ($p<0.001$). The average score for pharmacists' knowledge of nuclear pharmacy services was 1.61, with high scores obtained for the elements—knowledge of the nuclear pharmacist has additional salary in Saudi Arabia (1.76) and radiation safety considerations (1.73). The average score was obtained for knowledge of radiopharmaceutical products (1.63), and the highest score on knowledge was obtained for ^{131}I-Sodium Iodide capsule five mCi (for thyroid therapy) (1.8) and ^{201}Tl-Thallium solution five mCi (for cardiac imaging) (1.8). The resources used to access information about nuclear pharmacy services were drug information resources (93 (40.09%)), scientific literature (83 (35.78%)), and the internet (83 (34.48%)). **Conclusion:** The pharmacist's knowledge of nuclear pharmacy services and radiopharmaceutical products was poor. Therefore, to expand nuclear medicine, including pharmacy-related nuclear services, we recommend implementing the education and training program on nuclear pharmacy in Saudi Arabia.
Keywords: Knowledge, Pharmacist, Nuclear, Pharmacy, Saudi Arabia.

INTRODUCTION

Nuclear pharmacy is defined as "a specialty area of pharmacy practice involved with the preparation of radioactive materials to improve and promote health through the safe and effective use of radioactive drugs to diagnose and treat specific disease states.".[1] Radiopharmaceutical is the radioactive material or radioactive drug used in therapeutic and diagnostic procedures.[1] A radiopharmacy is "the place where radioactive drugs are prepared and dispensed. The radiopharmacy also serves as a depot for the storage of radioactive materials and nonradioactive supplies".[1,2] The main job of the pharmacist is to procure and prepare radiopharmaceutical products with high-quality procedures and follow up compliance with the handling of hazardous material. Besides, providing radiopharmaceutical-related information, monitoring patients undergoing radioactive treatment, and preventing radioactive-related problems, included distributive and clinical pharmacy activities.[1,3,4-9]

So far, more than 100 radioactive drugs are used to treat various disorders, including cancer and thyroid gland disorders; they are also used in pain management and diagnosis. Most radiopharmaceutical products are used for primary diagnosis, whereas other products are used in disease management.[10] The history of nuclear pharmacy began more than 30 years ago. In Saudi Arabia, the nuclear pharmacy was started in 1983 at King Faisal Hospital and Research Center under the Research and Development of radiopharmaceuticals.[11] The Saudi Society of Nuclear Medicine, founded in 2006, deals with radiopharmaceutical products and their diagnostic and therapy protocols.

Moreover, the Saudi Food and Drug Authority released various guidelines for manufacturing and preparing radioactive medications. So far, more than 50 nuclear medicine departments have used radioactive drugs or radiopharmaceutical products.[11] As a result, the knowledge of dealing with radiopharmaceutical products is essential. Nuclear pharmacy education has been a part of the Diploma in Pharmacy in various colleges of pharmacy in Saudi Arabia and the rest of the world.[12,5,13,14] However, the knowledge of nuclear pharmacy for graduated pharmacists is needed in the nuclear pharmacy practice.

To the best of our knowledge, information is lacking about the knowledge or perception of nuclear medicine with practical nuclear pharmacy.[15] Other studies have discussed the use of nuclear pharmacy services.[16,17] However, there are no studies conducted on the assessment of knowledge in nuclear pharmacy in Saudi Arabia, the Gulf, or the Middle Eastern countries, and in the rest of the world. Therefore, in this study, we aimed to assess pharmacists' knowledge in nuclear pharmacy in the Kingdom of Saudi Arabia.

METHODS

This is a cross-sectional survey on knowledge of pharmacists about nuclear pharmacy in Saudi Arabia. This is a self-reported electronic survey with pharmacists (both interns to consultants) and pharmacy specialists in Saudi Arabia. All non pharmacists and students and noncompleted surveys will be excluded from the study. The survey collected respondents' demographic information and their knowledge of selected nuclear pharmacy elements and radiopharmaceutical products in pharmaceutical care. The references of nuclear pharmacy elements in practice. We used the 5-point Likert response scale system with closed-ended questions to obtain responses. Based on the population size, the sample was calculated with a confidence level of 95% and *z* score of 1.96, the margin of error of 5–6.5%, the population percentage of 50%, and a drop-out rate of 10%. Thus, the sample size was calculated as 251–432 with a power of study of 80%.[18-20] The response rate required for the estimated sample size was at least 60–70 %.[20,21] The survey was distributed through social media such as WhatsApp and Telegram. After around 1-2 weeks, a reminder message was sent. Expert reviewers and pilot testing validated the survey. Moreover, various reliability tests such as McDonald's ω, Cronbach's α, Gutmann's λ2, and Gutmann's λ6 were analyzed. The data were collected through the Survey Monkey system. They were analyzed using the Statistical Package of Social Sciences (SPSS), Jeffery's Amazing Statistics Program (JASP), and Microsoft excel sheet version 16. We performed descriptive and frequency analysis, good of fitness test, and correlation analysis. In addition, we performed inferential analysis of factors affecting the knowledge of pharmacists about nuclear pharmacy and radiopharmaceutical products, as well as linear regression. The STROBE (strengthening the reporting of observational studies in epidemiology statement: guidelines for reporting observational studies) guided the reporting of the results of this survey.[22,23]

RESULTS

A total of 235 pharmacists responded to the survey questionnaire, with most of the responses obtained from the southern (82 (34.89%)), central (49 (20.85%)), and western region (47 (20%)) with statistically significant differences among the regions ($p<0.001$). Of them, 142 (63.96%) were male, and 80 (36.04%) were female responders, with statistically significant differences between them ($p<0.001$). Most of the responders were in the age group of 24–30 years (115 (48.94%)), followed by 31–35 years (57 (24.26%)), with statistically significant differences between all ages groups ($p<0.001$). About two-thirds of the pharmacists had obtained Bachelor's degree (149 (63.40%)) and Diploma in Pharmacy (75 (31.91%)), with statistically significant differences between all pharmaceutical degrees ($p<0.001$). Most pharmacists were staff pharmacists (119 (51.29%)) and interns (43 (18.53%)). The majority of the pharmacists had an experience of ≤ 3years (124 (52.99%)), with the majority of them practicing at the outpatient (26 (29.89%)) and inpatient pharmacy (19 (21.84%)), with statistically significant differences between them ($p<0.001$). There was a strong positive correlation between age (years) and years of experience at the pharmacy center, with Kendall's tau_b (0.705) and Spearman's rho (0.784) showing statistically significant differences between them ($p>0.05$). However, there was a negative medium correlation between position and years of experience at the pharmacy center, with Kendall's tau_b (−0.505) and Spearman's rho (−0.592) showing statistically significant differences between them ($p>0.05$) (Tables 1 and 2).

The total average scores of knowledge of pharmacists about nuclear pharmacy services was 1.61, with high scores obtained for elements "knowledge of the nuclear pharmacist has additional salary in Saudi Arabia" (1.76), "radiation safety considerations" (1.73), and "heard about the concept of a nuclear pharmacist's job" (1.86). In contrast, low scores were obtained for elements such as "familiar with King Abdulaziz City for sciences and technology regulations of radiopharmaceutical products" (1.48) and "off-labeled or non-approved radiopharmaceutical products" (1.54). Moreover, elements such as "the preparation of nonsterile radiopharmaceutical products" (1.55) and "the resources of nuclear pharmacy" (1.55) and showed statistically significant differences between their responses ($p<0.001$) (Table 3). The average score of elements "knowledge of radiopharmaceutical

Table 1: Demographic social information.

Nationality	Response Count	Response Percent	p-value (X2)
Central area	49	20.85%	< 0.001
North area	32	13.62%	
South area	82	34.89%	
East area	25	10.64%	
West area	47	20.00%	
Answered question	**235**		
Skipped question	**0**		
Gender	**Response Count**	**Response Percent**	
Male	142	63.96%	< 0.001
Female	80	36.04%	
Answered question	**222**		
Skipped question	**13**		
Age	**Response Count**	**Response Percent**	
24-30	115	48.94%	< 0.001
31-35	57	24.26%	
36-40	34	14.47%	
41-45	10	4.26%	
46-50	11	4.68%	
> 50	8	3.40%	
Answered question	**235**		
Skipped question	**0**		

Table 2: Demographic, social information.

Pharmacist Qualifications	Response Count	Response Percent	p-value (X2)
Diploma in Pharmacy	14	5.96%	
Bachelor's in pharmacy	149	63.40%	
Master	41	17.45%	
Pharm D	75	31.91%	
Ph. D	23	9.79%	
PGY 1	10	4.26%	
PGY 2	5	2.13%	
PGY 3	6	2.55%	
Fellowship	1	0.43%	
Other (please specify)	1	0.43%	
Answered question	**235**		
Skipped question	**0**		
Position Held	**Response Count**	**Response Percent**	
Director of Pharmacy	16	6.90%	<0.001
Assistant Director of Pharmacy	18	7.76%	
Supervisor	36	15.52%	
Pharmacy staff	119	51.29%	
Pharmacy Intern	43	18.53%	
Answered question	**232**		
Skipped question	**3**		
Years of experience at Physician career	**Response Count**	**Response Percent**	
Less than one year	56	23.93%	< 001
1-3	68	29.06%	
4-6	45	19.23%	
7-9	32	13.68%	
10-12	13	5.56%	
>12	20	8.55%	
Answered question	**234**		
Skipped question	**1**		
The practice area	**Response Count**	**Response Percent**	
Inpatient Pharmacy	19	21.84%	< 001
Outpatient Pharmacy	26	29.89%	
Satellite Pharmacy	1	1.15%	
Narcotics and Controlled	3	3.45%	
Extemporaneous Preparation	1	1.15%	
Clinical Pharmacy	10	11.49%	
Inventory Control	1	1.15%	
Drug Information	2	2.30%	
IV admixture	1	1.15%	
Community pharmacy	9	10.34%	
Pharmaceutical companies	7	8.05%	
Other (please specify)	7	8.05%	
Answered question	87		
Skipped question	148		

product in gulf formulary tender", "the highest score knowledge was ^{131}I-Sodium Iodide capsule five mCi (for thyroid therapy)" and "^{201}Tl-Thallium solution five mCi (for cardiac imaging)" was (1.63), (1.8), and (1.8), respectively. On the contrary, low scores were obtained for the elements "knowledge of radiopharmaceutical products was HIDA Kit 5 vials/Kit (with 99 mTc, Hepatobiliary kinetics evaluation)" (1.55), "DMSA Kits 5 vials/Kit (with 99 mTc) for renal cortical imaging" (1.56), and "Tin colloid Kits, five vials/kit (with 99 mTc for Hepatic and spleen imaging)" (1.57), with the statistically significant difference among the responses (p<0.001) (Table 4). Furthermore, resources that were used the most for nuclear pharmacy services were "Drug information resources" (93 (40.09%)), "Scientific literature" (83 (35.78%)), and "The Internet" (83 (34.48%)) (Table 5). The reliability test of McDonald's ω was 0.983, Cronbach's α was 0.983, Gutmann's λ2 was 0.983, and Gutmann's λ6 was 0.991.

Factors influencing the basic knowledge of nuclear pharmacy and radiopharmaceutical products

Various factors influence the basic knowledge of nuclear pharmacy. Five geographical locations might affect the knowledge of nuclear pharmacy. The West region had the lowest average knowledge score (1.4590) with statically significant differences (p=0.003). Six levels of age affected the knowledge. The age (24–30 years) lowest average score of knowledge (1.4704) with statically significant differences (p=0.012). Five levels of a position affected the knowledge with pharmacy intern's lowest average knowledge score (1.4574) with statically significant differences (p=0.036). There were no statistically significant differences in the basic knowledge of nuclear pharmacy versus gender (p=0.054) and years of experience (p=0.320). Furthermore, various factors might influence the knowledge of radiopharmaceutical products. Six levels of age affected the knowledge. The age (24–30 years) lowest average score of knowledge (1.4941) with statically significant differences (p=0.003). Five levels of a position affected the knowledge. The pharmacy supervisor had the highest average knowledge score (2.2756) with statically significant differences (p=0.004). There were no statically significant differences between location (p=0.056), gender (p=0.482), and years of experience (p=0.161) (Table 6).

This study demonstrated the relationship between basic knowledge of nuclear pharmacy and factors affecting it, such as location, age (years), gender, position held, and years of experience at the pharmacy center. The multiple regression model considered the

Table 3: Nuclear pharmacy or radiopharmacy assessment of basic knowledge.

	No knowledge		Little knowledge		Partial knowledge		Incomplete knowledge		Complete knowledge		Total	Weighted Average	p-value (X2)
Have you ever heard about the concept of radiopharmacy or nuclear pharmacy?	61.70%	145	21.70%	51	11.06%	26	2.13%	5	3.40%	8	235	1.64	< 001
Have you ever heard about the concept of a nuclear pharmacist's job?	59.31%	137	24.24%	56	9.09%	21	4.33%	10	3.03%	7	231	1.68	< 001
Are you familiar with King Abdulaziz City for sciences and technology regulations of radiopharmaceutical products	71.67%	167	17.17%	40	5.15%	12	3.43%	8	2.58%	6	233	1.48	< 001
Are you familiar with USP General Chapter Radiopharmaceuticals – Preparation, Compounding, Dispensing, and Repackaging USP 825	63.36%	147	21.55%	50	6.03%	14	5.60%	13	3.45%	8	232	1.64	< 001
Do you know the job description of a nuclear pharmacist?	64.66%	150	22.84%	53	6.03%	14	4.31%	10	2.16%	5	232	1.56	< 001
In Saudi Arabia, the nuclear pharmacist get more salary than regular pharmacist	57.58%	133	25.11%	58	7.36%	17	3.90%	9	6.06%	14	231	1.76	< 001
Do you know how to prepare non-sterile radiopharmaceutical products	66.67%	156	18.38%	43	10.68%	25	2.14%	5	2.14%	5	234	1.55	< 001
Do you know how to prepare sterile radiopharmaceutical products?	63.68%	149	21.79%	51	7.26%	17	3.42%	8	3.85%	9	234	1.62	< 001
Do you know the operation levels at the hospital pharmacy of radiopharmaceutical products?	67.10%	155	19.05%	44	8.23%	19	2.16%	5	3.46%	8	231	1.56	< 001
Do you know the radiation safety considerations?	58.12%	136	23.93%	56	8.55%	20	5.98%	14	3.42%	8	234	1.73	< 001
Do you know about the facilities and engineering control of the preparation of radiopharmaceutical products?	65.38%	153	20.94%	49	7.69%	18	2.14%	5	3.85%	9	234	1.58	< 001
Do you know about microbiological air and surface controlling during the compounding of radiopharmaceutical products?	66.24%	155	15.81%	37	10.26%	24	2.56%	6	5.13%	12	234	1.65	< 001
Do you know the cleaning and disinfecting for the preparation of radiopharmaceutical products?	58.80%	137	25.75%	60	8.58%	20	3.43%	8	3.43%	8	233	1.67	< 001
Do you know the international guidelines of nuclear pharmacy?	66.81%	155	18.53%	43	9.05%	21	3.02%	7	2.59%	6	232	1.56	< 001
Do you know about the clinical nuclear pharmacist?	66.09%	154	20.17%	47	8.15%	19	2.58%	6	3.00%	7	233	1.56	< 001
Do you know the off-labeled or non-approved radiopharmaceutical products?	67.09%	157	20.09%	47	7.69%	18	1.71%	4	3.42%	8	234	1.54	< 001
Do you now packaging and repacking radiopharmaceutical products?	64.53%	151	18.38%	43	9.40%	22	3.85%	9	3.85%	9	234	1.64	< 001
Do you know about nuclear toxicology?	60.26%	141	24.79%	58	7.26%	17	3.42%	8	4.27%	10	234	1.67	< 001
Do you know the storage of radiopharmaceutical products?	59.40%	139	25.21%	59	9.83%	23	1.28%	3	4.27%	10	234	1.66	< 001
Do you know the resources of nuclear pharmacy	67.38%	157	20.17%	47	6.01%	14	3.00%	7	3.43%	8	233	1.55	< 001
											Answered	**235**	
											Skipped	**0**	

Table 4: Radiopharmaceutical products assessment of basic knowledge at hospital.													
	No knowledge		Little knowledge		Partial knowledge		Incomplete knowledge		Complete knowledge		Total	Weighted Average	p-value (X2)
131 I-Sodium Iodide capsule 5mCi (for thyroid therapy)	52.79%	123	24.89%	58	15.02%	35	3.00%	< 001	4.29%	10	233	1.81	< 001
201Tl-Thallium solution 5 mCi (for cardiac imaging)	51.30%	118	28.26%	65	12.17%	28	4.78%	11	3.48%	8	230	1.81	< 001
67 GA-Gallium solution 5 mCi	60.09%	137	24.56%	56	7.46%	17	5.26%	12	2.63%	6	228	1.66	< 001
99m Tc-Technetium sterile generator TOR (600mCi) +/-5%, calibration should be specified at least three days from the delivery day.	63.20%	146	23.38%	54	8.23%	19	2.16%	5	3.03%	7	231	1.58	< 001
DMSA Kits 5 vials/Kit (with 99mTc) for renal cortical imaging	65.80%	152	21.21%	49	6.93%	16	3.03%	7	3.03%	7	231	1.56	< 001
DTPA Kits 5 vials/Kit (with 99m Tc, for renal function imaging)	63.79%	148	23.28%	54	6.90%	16	2.59%	6	3.45%	8	232	1.59	< 001
HIDA Kit 5 vials/Kit (with 99mTc, Hepatobiliary kinetics evaluation)	65.65%	151	22.61%	52	6.09%	14	2.61%	6	3.04%	7	230	1.55	< 001
I - 131 MIBG 1 mCi (for adrenal imaging) .	64.22%	149	23.28%	54	6.47%	15	3.45%	8	2.59%	6	232	1.57	< 001
131 I-Sodium Iodide capsule 100 mCi (for thyroid therapy)	53.51%	122	26.32%	60	7.46%	17	8.33%	19	4.39%	10	228	1.84	< 001
MAA Kits 5 vials/Kit (99mTc, for lung perfusion evaluation).	62.50%	145	26.29%	61	5.17%	12	2.59%	6	3.45%	8	232	1.58	< 001
MAG3 Kits 5 vials/Kit (with 99mTc for Renal Execratory function evaluation)	63.79%	148	21.98%	51	9.05%	21	1.72%	4	3.45%	8	232	1.59	< 001
Medronate II (MDP) Bone Kit 5 vials/kit (with 99 mTc for Bone imaging).	64.66%	150	21.98%	51	6.03%	14	3.45%	8	3.88%	9	232	1.6	< 001
Monoclonal Antibody Kits (99 mTc with Leukocyte for WBC scan)	60.94%	142	24.46%	57	7.73%	18	2.58%	6	4.29%	10	233	1.65	< 001
Nanocolloid Kit 5 vials/kit (with 99 mTc for Lymphoscintigraphy imaging)	59.48%	138	25.86%	60	7.76%	18	2.59%	6	4.31%	10	232	1.66	< 001
PYP Kits 5 vials/kit (with 99 mTc, for cardiac imaging)	63.09%	147	24.46%	57	7.73%	18	1.29%	3	3.43%	8	233	1.58	< 001
Sestamibi Kits 5 vials/kit (with 99mTc, for cardiac, Breast, and Parathyroid imaging)	64.94%	150	22.08%	51	6.93%	16	2.16%	5	3.90%	9	231	1.58	< 001
Stannous or other agents 5 vials/kit for 99mTc, for Red Blood Cell)	63.79%	148	21.55%	50	6.90%	16	3.02%	7	4.74%	11	232	1.63	< 001
Sulfur colloid Kits, 5 vials/kit (with 99mTc for Hepatic and spleen imaging).	63.79%	148	21.55%	50	6.47%	15	3.88%	9	4.31%	10	232	1.63	< 001
Tin colloid Kits, 5 vials/kit (with 99 mTc for Hepatic and spleen imaging).	66.52%	155	19.31%	45	9.01%	21	0.86%	2	4.29%	10	233	1.57	< 001
											Answered	**234**	
											Skipped	**1**	

Table 5: The most resources used for nuclear pharmacy information.

Answer Choices	Responses	
Healthcare practitioners	72	31.03%
Scientific literature	83	35.78%
Peer discussions	57	24.57%
Medical association literature/guidelines/recommendations	63	27.16%
Drug information resources (Lexicomp-drug information, Micromedex, Epocrates ..etc	93	40.09%
SFDA website	57	24.57%
Drug Bulletin	36	15.52%
Relatives and friends	60	25.86%
Nuclear pharmacy education courses	60	25.86%
Internet	80	34.48%
The drug information center at the hospital	59	25.43%
Awareness lectures in a hospital	50	21.55%
Awareness lectures primary healthcare center	47	20.26%
Healthcare care awareness events at the market	38	16.38%
Answered	**232**	
Skipped	**3**	

nuclear pharmacy basic knowledge dependent variable, and factors were considered an expletory variable. Our results show a weak relationship (R=0.250; p=0.17) between the basic knowledge of nuclear pharmacy and the factors affecting it. However, no factors had a relationship by using standardized coefficients beta considered nonstatistical significant (p>0.05), and through multiple regression model. It was confirmed by the Bootstrap model (Table 7). The relationship between radiopharmaceutical products knowledge and factors location, age (years), pharmacist gender, position held, and years of experiences in a pharmacy career. It was demonstrated through a multiple regression model and considered the nuclear pharmacy basic knowledge dependent factors were regarded as the expletory variable. There is a weak relationship (R=0.219; p=0.062) between knowledge of radiopharmaceutical products and factors affecting it with non-statistically significant differences between them (p>0.05). Moreover, no factors had a relationship by using the Standardized Coefficients Beta, considered non-statistically significant (p>0.05) and through multiple regression model. It was confirmed by the Bootstrap model (Table 8).

DISCUSSION

For the past 30 years, there was expanding nuclear medicine science founded in Saudi Arabia, the first center in 1983.[11] Currently, several healthcare organizations use nuclear medicine in the central, western, and eastern provinces of Saudi Arabia. Each center had a consultant nuclear medicine physicians, and technicians, nurses, and a few pharmacists.[11,17,24,25] The pharmacy college has upgraded its curriculum degrees from Bachelor to Pharm D,[12] including the nuclear pharmacy courses. The knowledge of nuclear pharmacy was mandated to increase the professionalism of nuclear pharmacists in nuclear medicine and prepare the pharmacists to work and provide better services in the field of nuclear medicine. The current investigation is to tackle the target knowledge of pharmacists in nuclear pharmacy science. The study was a cross-section design with a convenient sample. Moreover, the survey conducted in this study was validated with a high-reliability score.

The majority of the pharmacists responded from the southern region as the author of this article resides there. Therefore, it is easy for the pharmacists belonging to this region to respond from the southern region. There were different samples between sites, which is expected because it was a convenient sample, not a cluster sample, which is accepted in the research.[18-20] Most of the responders were male, which might be because it was easy for the authors to communicate with the male pharmacists. Most of the responders were a young group of 24–30. Furthermore, pharmacists with a Bachelor's degree or Diploma had less experience and were in low positions in employment. There was a strong correlation between age and expected experiences; passing more years of age will get more experiences. However, there was a negative correlation between the experience of the pharmacist and his/her position. Some pharmacists were hired as managers even though they had limited experience.

The average score of pharmacists' knowledge about nuclear pharmacy was low, with only 30% of the responders having particular knowledge. Most pharmacists were not working at nuclear medicine centers, consistent with previous studies.[24,25] On the other hand, the responders had the highest knowledge of the nuclear pharmacy field; mainly, the nuclear pharmacist jobs got more additional salary and the radiation safety concept. Moreover, they knew about a nuclear pharmacist's job, that's expected because the responders were familiar with pharmacists employment regulations, and might the pharmacists had experienced with medications safety services or even had medication safety education during the school of pharmacy study.[12-14,5]

Moreover, most healthcare providers, including pharmacists, are not familiar with the nuclear pharmacist jobs as there are only a few pharmacists who work in the department of nuclear medicine.[11,17,24,25] The previous study also reveals less awareness among healthcare providers about nuclear pharmacists' jobs.[7] In contrast, they had the lowest score knowledge about local guidelines or preparation of parenteral radioactive medications or the absence of nuclear pharmacy resources. That's related to might few pharmacists working at nuclear medicine departments, or the pharmacy department did not provide nuclear pharmacy services.[24,25] In this study, pharmacists' knowledge regarding radiopharmaceutical products is inferior, as reported by a previous study.[7] The highest knowledge with commonly used radioactive drug-like 131-Sodium Iodide ^{201}TI-Thaluim solution might be different from radioactive drugs used in an earlier study.[16] Most of the responders used drug information resources (e.g., PubMed) and scientific literature from the internet on nuclear pharmacy, which shows that the pharmacists were more familiar with drug information resources and online resources. Another study showed that the availability of nuclear pharmacy at healthcare organizations is only 16%.[7] In this study, pharmacist's knowledge of nuclear medicine was affected by various factors, such as location. The southern region scored the lowest about knowledge of nuclear pharmacy, which may be because the pharmacists were not properly working in nuclear medicine or did not provide nuclear pharmacy services at their healthcare institutions. That is declaring that's any place that any place does not has the nuclear medicine practice properly. Thus, their

Table 6: Factors (average scores) influencing the Nuclear pharmacy basic knowledge and Radiopharmaceutical products knowledge.

		Nuclear pharmacy basic knowledge							Radiopharmaceutical products knowledge						
	Factors	N	Average scores	Std. D	Median	Lower Bound	Upper Bound	P-value	N	Average scores	Std. D	Median	Lower Bound	Upper Bound	P-value
Region	Central	46	1.6049	0.6888	1.4500	1.4003	1.8094	0.003	46	1.5595	.79593	1.2705	1.3231	1.7959	0.056
	North	28	1.6012	0.5723	1.4500	1.3793	1.8232		28	1.6638	.60230	1.5263	1.4303	1.8974	
	South	76	1.6001	0.8336	1.2000	1.4097	1.7906		76	1.6465	.91478	1.2164	1.4375	1.8556	
	East	25	1.8558	0.8684	1.6000	1.4973	2.2142		25	1.8000	.92043	1.5263	1.4201	2.1799	
	West	44	1.4590*	0.8816	1.0500	1.1910	1.7271		44	1.5438	.91980	1.1053	1.2641	1.8234	
	Total	219							219						
Age	24-30	112	1.4704*	.64256	1.2000	1.3501	1.5907	0.012	112	1.4941*	.74511	1.1623	1.3546	1.6336	0.003
	31-35	52	1.5464	.41376	1.4750	1.4312	1.6616		52	1.5675	.49475	1.4868	1.4298	1.7053	
	36-40	30	1.9580	1.03841	1.7250	1.5702	2.3457		30	2.0080	1.08964	1.6842	1.6011	2.4149	
	41-45	9	1.5526	.83278	1.0000	.9125	2.1928		9	1.5712	.71326	1.5556	1.0229	2.1194	
	46-50	8	2.0000	1.37451	1.6250	.8509	3.1491		8	2.1250	1.38565	1.7105	.9666	3.2834	
	> 50	8	2.1313	1.78464	1.0000	.6393	3.6232		8	2.0197	1.82407	1.0263	.4948	3.5447	
	Total	219							219						
Gender	Male	139	1.5385	.74142	1.2500	1.4142	1.6629	0.054	139	1.5939	.83451	1.2632	1.4539	1.7338	0.482
	Female	80	1.7126	.86371	1.4500	1.5204	1.9048		80	1.6855	.88998	1.4737	1.4874	1.8835	
	Total	219							219						
Employment	Director of Pharmacy	15	1.3319	.50822	1.0500	1.0505	1.6134	0.036	15	1.3719	.41464	1.2105	1.1423	1.6016	0.004
	Assistant director of Pharmacy	16	1.5347	.41844	1.5132	1.3117	1.7577		16	1.7924	.59111	1.8363	1.4774	2.1074	
	Supervisor	33	2.1477	1.34332	1.6500	1.6714	2.6240		33	2.2756*	1.39859	1.6316	1.7796	2.7715	
	Pharmacy Staff	113	1.5420	.58472	1.4000	1.4330	1.6510		113	1.4788	.57873	1.2632	1.3710	1.5867	
	Pharmacy intern	42	1.4574*	.72872	1.1500	1.2303	1.6845		42	1.5459	.90120	1.1579	1.2651	1.8267	
	Total	219							219						
Experiences	<1	55	1.4475	.64810	1.1500	1.2723	1.6227	0.320	55	1.4902	.76568	1.1579	1.2832	1.6972	0.161
	1-3	64	1.5090	.58049	1.4250	1.3640	1.6540		64	1.5154	.63430	1.4474	1.3569	1.6738	
	4-6	43	1.6837	.75893	1.5263	1.4501	1.9172		43	1.6237	.78820	1.3684	1.3811	1.8663	
	7-9	27	1.6872	.84359	1.5000	1.3535	2.0209		27	1.7051	.85772	1.4706	1.3658	2.0444	
	10-12	13	1.6634	.75986	1.4500	1.2042	2.1225		13	1.9757	1.01048	1.8947	1.3651	2.5863	
	>12	17	2.0647	1.51573	1.1500	1.2854	2.8440		17	2.1118	1.52187	1.1579	1.3293	2.8943	
	Total	219							219						

knowledge of nuclear pharmacy will be poor. Other factors that might affect the knowledge of pharmacists of nuclear pharmacy were age and position held. The pharmacy interns or newly graduated pharmacists scored the lowest, expected because they have not practiced nuclear pharmacy services yet. The gender or number of years of experience did not influence the pharmacist knowledge because the male or female graduates from the same school of pharmacy did not practice nuclear pharmacy regardless of the period of experience.

However, the supervisor had the highest knowledge of medicines because they might participate in the procurement and reporting of radioactive pharmaceuticals by following the medication's usage or documenting radioactive medication safety for drug-related problems.[26,27] Some factors might influence the radioactive drug knowledge, such as location or gender, or years of experience because the nuclear pharmacy services have not existed in their regions. There was a correlation between knowledge of nuclear pharmacy services and radiopharmaceutical products, which was expected because of the pharmacy practice and nuclear pharmacy services they will be familiar with the radioactive drug. However, our results showed no positive or negative correlation between pharmacist knowledge of nuclear pharmacy services or radioactive drug knowledge and the five factors (location, age, gender, position, and years of experience). However, there was some difference in the knowledge-based on the aforementioned factors.

LIMITATION

This study has some limitations. First, the unequal distribution of responders

Table 7: Multiple regression of Factors with the Nuclear pharmacy basic knowledge[a]

Model		R	R Square	F	Sig.	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
						B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.250[b]	.062	2.831	.017[b]	1.127	.323		3.492	.001	.491	1.764		
	Location					-.047-	.039	-.081-	-1.196-	.233	-.124-	.030	.950	1.053
	Age (years)					.124	.070	.206	1.762	.080	-.015-	.262	.322	3.110
	Pharmacist gender					.085	.112	.052	.754	.452	-.137-	.306	.936	1.069
	Position Held					.046	.056	.063	.827	.409	-.064-	.157	.755	1.324
	Years of experience at pharmacy career					.031	.063	.059	.492	.623	-.094-	.156	.302	3.312

a. Dependent Variable: Nuclear pharmacy basic knowledge, [b] Predictors: (Constant), Location, Age (years), Pharmacist gender, Position Held, and Years of experiences at pharmacy career.

Bootstrap for Coefficients							
Model		B	Bootstrap[a]				
			Bias	Std. Error	Sig. (2-tailed)	95% Confidence Interval	
						Lower	Upper
1	(Constant)	1.127	-.017-	.283	.001	.545	1.659
	Location	-.047-	.002	.038	.218	-.118-	.032
	Age (years)	.124	.000	.095	.193	-.057-	.333
	Pharmacist gender	.085	.005	.111	.443	-.121-	.318
	Position Held	.046	.000	.050	.352	-.052-	.147
	Years of experiences at pharmacy career	.031	.002	.064	.604	-.089-	.164

a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

between locations and the unequal number of responders between males and females. Second, the unequal distribution of age, position held, and years of experience. The majority of the responders were young with less experience, that's shows the representative of their knowledge about nuclear pharmacy. Third, although the number of samples did reach an optimal level with an appropriate effect size, more sampling was needed to get 400 responders in further studies. Finally, it was not easy to compare the current results with previous studies because they did not exist.

CONCLUSION

In conclusion, pharmacists' knowledge about nuclear pharmacy services and radioactive medications is deficient in the Kingdom of Saudi Arabia. Furthermore, the knowledge of pharmacists is varied, which is due to various factors. For example, pharmacists of a particular location or young people had less knowledge of nuclear pharmacy. However, there is no correlation between specific characteristics, for instance, location, age, gender, positions, and experiences. Therefore, we recommend further studies with large sample size and nuclear pharmacy-related issues in Saudi Arabia.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Consent for Publications

Informed consent was obtained from all the participants

Ethical Approval

This research was exempted from research and ethical committee or an institutional review board (IRB) approval.

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ABBREVIATIONS

KSA: Kingdom of Saudi Arabia; **SPSS:** Statistical Package of Social Sciences; **JASP:** Jeffery's Amazing Statistics Program; **Strobe:** Strengthening the reporting of observational studies in epidemiology statement: guidelines for reporting observational studies.

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Table 8: Multiple regression of Factors with the and Radiopharmaceutical products knowledge [a]

Model		R	R Square	F	Sig.	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
						B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.219 [b]	.048	2.141	.062[b]	1.315	.351		3.742	.000	.622	2.008		
	Location					-.023-	.043	-.036-	-.530-	.596	-.107-	.061	.950	1.053
	Age (years)					.072	.077	.111	.941	.348	-.079-	.223	.322	3.110
	Pharmacist gender					-.003-	.122	-.002-	-.023-	.982	-.244-	.238	.936	1.069
	Position Held					.012	.061	.015	.192	.848	-.109-	.132	.755	1.324
	Years of experience at pharmacy career					.074	.069	.130	1.072	.285	-.062-	.210	.302	3.312

a. Dependent Variable: Knowledge of radiopharmaceutical products, [b] Predictors: (Constant), (Constant), Location, Age (years), Pharmacist gender, Position Held, and Years of experiences at pharmacy career

Bootstrap for Coefficients							
Model		B	Bootstrap[a]				
			Bias	Std. Error	Sig. (2-tailed)	95% Confidence Interval	
						Lower	Upper
1	(Constant)	1.315	.001	.311	.002	.660	1.901
	Location	-.023-	.001	.040	.562	-.098-	.057
	Age (years)	.072	-.002-	.087	.425	-.088-	.249
	Pharmacist gender	-.003-	.003	.120	.982	-.224-	.248
	Position Held	.012	-.002-	.054	.819	-.095-	.116
	Years of experiences at pharmacy career	.074	.001	.065	.254	-.056-	.209

a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

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