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Assessment of Food-Drug Interaction Knowledge among Pharmacists and Senior Pharmacy Students: Impact of Training Interventions

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Abstract

Food–drug interactions (FDIs) emerge when a drug and a food item, dietary supplement, or plant-derived nutrient interact through chemical, physical, or physiological processes. Pharmacists have a critical role in identifying and managing such interactions. This study aimed to explore factors that influence FDI knowledge and comprehension among licensed pharmacists and final-year pharmacy students. Additionally, in senior pharmacy students, the study assessed how FDI training affected knowledge both immediately and over time. Participants were asked to complete the Turkish FDI Knowledge Scale online, which has been previously validated. Senior pharmacy students first completed the scale, followed by an in-person verbal training session to examine its impact on FDI understanding. Subsequently, the same scale was re-administered at two later time points to assess short- and long-term knowledge retention. Binary logistic regression was employed to identify predictors of achieving good or very good FDI knowledge scores according to the scale.

A total of 356 individuals participated, with a mean age of 28.99 ± 7.79 years. When comparing educational levels, senior pharmacy students had the lowest mean knowledge score (9.23 ± 3.78), while pharmacists with specialty training or ongoing postgraduate education had the highest scores (17.00 ± 2.73). Participants who never provided counseling about FDIs had the lowest average score (8.80 ± 4.18), while those who frequently provided counseling had the highest (14.28 ± 3.68). Age and years of professional experience were positively associated with knowledge scores (Spearman's r: age 0.354; experience 0.419; $p < 0.001$). Following FDI training, senior pharmacy students showed a significant increase in mean scores ($p < 0.001$), rising from 8.85 ± 3.57 pre-training to 16.24 ± 3.15 shortly after, with scores remaining stable in the long term (16.67 ± 2.59; $p = 0.307$). Female gender (OR 1.842; 95% CI 1.027–3.302) and high self-rated FDI knowledge (OR 18.311; 95% CI 4.879–68.718) were significant predictors of good or very good knowledge scores. Since senior pharmacy students had the lowest FDI knowledge, and pharmacists with specialty or continuing education had the highest, integrating FDI courses into undergraduate curricula and providing ongoing professional training is recommended to improve pharmacists' competence in this area.

Keywords: Food–drug interactions, Pharmacists, Pharmacy students, Health personnel, Scale

Introduction

Food–drug interactions (FDIs) occur when a drug comes into contact with a food or nutrient from dietary supplements or botanical sources, potentially altering its effect through chemical, physical, or physiological mechanisms. Such interactions can lead to reduced therapeutic efficacy or adverse clinical outcomes by modifying pharmacokinetics or pharmacodynamics [1]. The clinical relevance of FDIs is well documented [2]. For instance, combining angiotensin-converting enzyme inhibitors with potassium-rich foods like bananas or potatoes can increase hyperkalemia risk [3]. Similarly, warfarin interacts with foods high in vitamin K, such as green leafy vegetables, which counteract its anticoagulant effect and may result in thrombosis [4]. FDIs are an increasing concern in healthcare and represent a major obstacle for medication users [5]. Healthcare providers should actively manage FDI-related

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risks, including changes in drug effectiveness, potential toxicity, and fluctuations in patients' health [6]. Pharmacists often serve as the first point of consultation for patients regarding medications, making their knowledge of FDIs vital for preventing adverse drug events and ensuring treatment success [7]. To date, no study has evaluated FDI knowledge levels among pharmacists and the factors influencing this in Türkiye.

This study aimed to assess the FDI knowledge of licensed pharmacists working in various practice settings in Türkiye and senior pharmacy students at a university, using a validated scale developed by Karagoz *et al*. [8]. The study also sought to identify factors associated with higher knowledge and understanding of FDIs and to examine the short- and long-term impact of targeted FDI training on senior pharmacy students.

Materials and Methods

Study population

The study included senior pharmacy students and licensed pharmacists across Türkiye. In 2024, there were approximately 26,000 licensed pharmacists and 1,800 senior pharmacy students. Data on pharmacists were obtained through the Turkish Pharmacists' Association, while student numbers were derived from the Student Selection and Placement Centre's publicly available database. Türkiye offers two specialty pharmacy programs—clinical pharmacy and phytopharmacy—allowing graduates to pursue a minimum of three years of additional voluntary training. These programs aim to develop pharmacy specialists capable of advising both patients and healthcare professionals on medications and herbal products in clinical practice. Participants were selected via convenience sampling. Inclusion criteria were being a licensed pharmacist or senior pharmacy student and providing consent to participate.

Ethics committee approval

Approval for the study was obtained from the Institutional Review Board of Inonu University (2024/5010, September 24, 2024).

FDI knowledge level scale

In 2022, Karagöz *et al*. designed and validated a Turkish-language FDI Knowledge Scale intended for healthcare professionals (HCPs). The scale comprises 21 items, with response options "true," "false," or "I do not know." Its internal consistency was reported as strong, with a Cronbach's alpha of 0.787. FDI knowledge scores were categorized into four levels: low (0–5), intermediate (6–11), good (12–15), and very good (16–21) [8]. Written permission to use this scale for the current study was obtained from the corresponding author of the original publication.

Data collection

Data were collected online using Google Forms, which allowed the implementation of the FDI Knowledge Scale and recording of participant information. The survey link was shared electronically through WhatsApp® groups or directly via colleagues, targeting individuals who met the inclusion criteria. Participants were encouraged to forward the survey to other eligible colleagues. All participants were informed that responses would remain confidential, would be used solely for research purposes, and would be anonymized. Participation was voluntary, with the option to withdraw at any time, and no monetary compensation was provided. Consent to participate was obtained at the beginning of the questionnaire. Collected data included age, sex, current educational level, pharmacy practice area, regular medication usage, frequency of FDI counseling, self-assessed FDI knowledge, and interest in future FDI training.

The questionnaire contained five sections. Section 1 provided an overview of the study. Section 2 collected informed consent. Section 3 recorded sociodemographic characteristics (sex, age, education level, current pharmacy field, years of work experience, regular medication status). Section 4 focused on participants' opinions regarding FDIs (self-assessed knowledge, counseling frequency, main sources of FDI information, willingness to attend future training). Section 5 comprised the 21-item FDI Knowledge Scale. Completion required approximately 20 minutes. Data collection occurred between September and December 2024.

Training of senior pharmacy students on FDIs

Pharmacy education in Türkiye spans five years. Fifth-year students participated in an optional component of the required course 'Pharmacy Practice,' which covers patient counseling and education. The course includes detecting FDIs, identifying drug classes with high FDI risk, strategies for prevention, and managing interactions. After initial scale administration, students received a 90-minute face-to-face visual and verbal training session provided by a faculty member from the Clinical

Pharmacy Department. The session covered FDI definitions, types, clinical consequences with examples, and practical recommendations. Students engaged in a case study to reinforce learning, and useful databases for solving clinical FDI scenarios were introduced. The scale was administered immediately after training to assess short-term knowledge improvement and again eight weeks later to evaluate long-term retention.

Sample size

A pilot study with the first 50 participants was conducted to estimate the required sample size. The primary objective was to determine the proportion of licensed pharmacists and senior pharmacy students achieving good or very good FDI knowledge according to the scale. Based on pilot data, 70.0% of participants reached this knowledge level. Using the Raosoft® online sample size calculator, the minimum sample size was calculated as 319, assuming a population of 27,800, a 5% margin of error, and a 95% confidence level. The final study included 306 additional participants, resulting in a total sample of 356 individuals.

Statistical analysis

All statistical analyses were carried out using IBM SPSS Statistics for Windows®, version 27.0.1.0 (IBM Corp., Chicago, IL, USA). Continuous variables with normal distribution were presented as mean ± standard deviation, whereas those not normally distributed were expressed as median [interquartile range, IQR]. Categorical variables were summarized as counts and percentages. Appropriate parametric or non-parametric tests were applied to examine differences in continuous variables across groups. For post-hoc pairwise testing, the Bonferroni method was used when variance homogeneity was met, while the Games-Howell procedure was applied when this assumption was violated. Effect sizes for statistically significant comparisons were calculated using Cohen's d for two-group comparisons and Eta-squared for comparisons involving more than two groups. Chi-square tests were conducted to compare categorical variables, and the effect size for significant results was determined using Cramer's V with 95% confidence intervals derived from 1,000 bootstrap samples. Conventional benchmarks were applied for interpreting effect sizes: Cohen's d of 0.20, 0.50, and 0.80 indicate small, medium, and large effects, respectively; Eta-squared values of 0.01, 0.06, and 0.14 indicate small, medium, and large effects for ANOVA; and Cramer's V of 0.10, 0.30, and 0.50 indicate small, medium, and large effects for categorical associations [9]. Spearman's rank correlation was used for age and work experience due to their non-normal distribution. Kappa statistics assessed agreement between participants' self-rated FDI knowledge and their scale-based FDI knowledge scores. Binary logistic regression was performed to identify factors associated with achieving a good or very good score on the FDI knowledge scale. Statistical significance was defined as $p < 0.05$.

Results and Discussion

A total of 356 participants were included in the final analysis, and no missing data were recorded. The mean age was 28.99 ± 7.79 years, while the median [IQR] work experience was 2.00 [0.00–6.00] years. The sample comprised 261 licensed pharmacists (73.31%) holding at least a bachelor's degree, and 95 senior pharmacy students (26.69%). The mean score on the FDI knowledge scale was 12.42 ± 4.23. Based on the scale, participants were categorized as: low (n=28, 7.87%), intermediate (n=81, 22.75%), good (n=159, 44.66%), and very good (n=88, 24.72%).

Participants' main sources of FDI information included: package inserts (n=177, 49.72%), scientific literature (n=100, 28.09%), online search engines (n=48, 13.48%), textbooks (n=14, 3.93%), healthcare professionals (n=9, 2.53%), and social media (n=8, 2.25%). In this study, the internal consistency of the scale was high, with Cronbach's alpha = 0.840, indicating good reliability [10]. Participant characteristics are summarized in **Table 1**.

Table 1. Characteristics of participants

Characteristic (N = 356)	Scale-based FDI Knowledge Score, Mean ± SD	Effect Size (95% CI)	Value	p
Sex		0.30*** (0.08–0.52)		0.008*
Male, n (%)	11.57 ± 4.57		122 (34.27)	
Female, n (%)	12.87 ± 3.98		234 (65.73)	

Current Education Level		0.271**** (0.192–0.338)	< 0.001**
Senior student, n (%)	9.23 ± 3.78	95 (26.69)	
Bachelor's degree, n (%)	12.97 ± 3.44	176 (49.44)	
Having a master's or doctoral degree or being in continuum, n (%)	13.73 ± 4.30	56 (15.73)	
Having a specialty in pharmacy degree or being in continuum, n (%)	17.00 ± 2.73	29 (8.15)	
Participants' University Type for Their Bachelor's Degree		0.633*	
Government, n (%)	12.40 ± 4.21	341 (95.79)	
Private, n (%)	12.93 ± 4.89	15 (4.21)	
The Pharmacy Field in Which Participants Currently Work		0.264**** (0.181–0.327)	< 0.001**
Community pharmacy, n (%)	12.95 ± 3.58	103 (28.93)	
Senior student, n (%)	9.23 ± 3.78	95 (26.69)	
Hospital pharmacy, n (%)	13.47 ± 3.51	90 (25.28)	
Specialty in pharmacy, n (%)	17.04 ± 2.63	26 (7.30)	
Academy, n (%)	13.52 ± 5.06	21 (5.90)	
Others, n (%)	12.95 ± 3.53	21 (5.90)	
Receiving Regular Drug Treatment		0.986*	
Yes, n (%)	12.43 ± 4.16	84 (23.60)	
No, n (%)	12.42 ± 4.26	272 (76.40)	
The Frequency of Being Counselled on FDIs		0.095**** (0.040–0.150)	< 0.001**
Never, n (%)	8.80 ± 4.18	15 (4.21)	
Seldom, n (%)	11.41 ± 4.18	136 (38.20)	
Sometimes, n (%)	12.90 ± 4.07	137 (38.48)	
Often, n (%)	14.28 ± 3.68	68 (19.10)	
Participants' Self-Perception of FDI Knowledge		0.247**** (0.169–0.314)	< 0.001**
Low, n (%)	9.76 ± 3.93	96 (26.97)	
Intermediate, n (%)	12.26 ± 3.94	170 (47.75)	
Good, n (%)	15.62 ± 2.83	79 (22.19)	
Very good, n (%)	15.09 ± 2.66	11 (3.09)	
Participants' Willingness to Have Training on FDIs in the Future		0.703**	
Yes, n (%)	12.49 ± 4.17	300 (84.27)	
No, n (%)	12.50 ± 4.69	14 (3.93)	
Not sure, n (%)	11.90 ± 4.61	42 (11.80)	

* Independent samples t-test
** One-way ANOVA
*** Cohen's d
**** Eta-squared
Bold values indicate statistically significant findings.

Effect size evaluation for mean differences in FDI knowledge revealed that participants' educational level, current pharmacy practice area, and self-perceived FDI knowledge had large effects on the scores. In contrast, sex showed a small-to-medium effect, while frequency of counseling on FDIs demonstrated a medium-to-large effect.

Pairwise comparisons of FDI knowledge scores across

education levels using the Bonferroni test revealed significant differences. Senior pharmacy students scored markedly lower than participants with a bachelor's degree, master's or doctoral degrees (or ongoing postgraduate education), and those with a specialty pharmacy qualification ($p < 0.001$ for all comparisons). No significant difference was found between bachelor's degree holders and master's/doctoral/continuing education participants ($p = 1.000$). Participants with a specialty pharmacy degree scored significantly higher than all other groups ($p < 0.001$).

FDI knowledge scores were also analyzed according to the pharmacy field in which participants were currently practicing, with detailed pairwise comparisons provided in **Table 2**.

Table 2. Pairwise comparisons of FDI knowledge scores by current pharmacy field

Comparison Groups	Standard Error	Mean Difference (ij)	p-value
Senior student (i) vs Academy (j)	0.88	−4.29	<0.001
Senior student (i) vs Community pharmacy (j)	0.52	−3.72	<0.001
Senior student (i) vs Hospital pharmacy (j)	0.54	−4.24	<0.001
Senior student (i) vs Specialty in pharmacy (j)	0.81	−7.81	<0.001
Senior student (i) vs Others (j)	0.88	−3.72	<0.001
Academy (i) vs Senior student (j)	0.88	4.29	<0.001
Academy (i) vs Community pharmacy (j)	0.88	0.57	1.000
Academy (i) vs Hospital pharmacy (j)	0.89	0.06	1.000
Academy (i) vs Specialty in pharmacy (j)	1.07	−3.52	0.017
Academy (i) vs Others (j)	1.12	0.66	1.000
Community pharmacy (i) vs Senior student (j)	0.52	3.72	<0.001
Community pharmacy (i) vs Academy (j)	0.88	−0.57	1.000
Community pharmacy (i) vs Hospital pharmacy (j)	0.53	−0.52	1.000
Community pharmacy (i) vs Specialty in pharmacy (j)	0.80	−4.09	<0.001
Community pharmacy (i) vs Others (j)	0.86	0.09	1.000
Hospital pharmacy (i) vs Senior student (j)	0.54	4.24	<0.001
Hospital pharmacy (i) vs Academy (j)	0.89	−0.06	1.000
Hospital pharmacy (i) vs Community pharmacy (j)	0.53	0.52	1.000
Hospital pharmacy (i) vs Specialty in pharmacy (j)	0.81	−3.57	<0.001
Hospital pharmacy (i) vs Others (j)	0.87	0.60	1.000
Specialty in pharmacy (i) vs Senior student (j)	0.81	7.81	<0.001
Specialty in pharmacy (i) vs Academy (j)	1.07	3.52	0.017
Specialty in pharmacy (i) vs Community pharmacy (j)	0.80	4.09	<0.001
Specialty in pharmacy (i) vs Hospital pharmacy (j)	0.81	3.57	<0.001
Specialty in pharmacy (i) vs Others (j)	1.06	4.18	0.001
Others (i) vs Senior student (j)	0.88	3.72	<0.001
Others (i) vs Academy (j)	1.12	−0.66	1.000
Others (i) vs Community pharmacy (j)	0.86	−0.09	1.000
Others (i) vs Hospital pharmacy (j)	0.87	−0.60	1.000
Others (i) vs Specialty in pharmacy (j)	1.06	−4.18	0.001

NA Not applicable; the Bonferroni test was applied where homogeneity of variance assumptions were met.
Statistically significant results are highlighted in bold throughout.

Scale-based FDI knowledge scores were analyzed according to how frequently participants received counseling regarding FDIs—that is, how often pharmacists provide FDI information on request—using

the Bonferroni post-hoc test. Individuals who reported never receiving counseling scored significantly lower than those counseled sometimes ($p = 0.001$) or often ($p < 0.001$). Similarly, participants who were seldom counseled had lower scores compared with those counseled often ($p < 0.001$) or sometimes ($p = 0.016$). No significant differences were observed between participants counseled sometimes versus often ($p = 0.131$) or between never versus seldom counseled ($p = 0.109$).

Participants' scale-based FDI knowledge scores were also compared based on their self-assessed FDI knowledge **(Table 3)**.

Table 3. Pairwise comparison of FDI knowledge scores by self-perceived FDI knowledge levels

Comparison Groups	Low (j)	Intermediate (j)	Good (j)	Very good (j)
Low (i)	NA	Mean Difference (ij): −2.50Standard Error: 0.50p < 0.001	Mean Difference (ij): −5.86Standard Error: 0.51p < 0.001	Mean Difference (ij): −5.33Standard Error: 0.90p < 0.001
Intermediate (i)	Mean Difference (ij): 2.50Standard Error: 0.50p < 0.001	NA	Mean Difference (ij): −3.56Standard Error: 0.44p < 0.001	Mean Difference (ij): −2.83Standard Error: 0.86p = 0.026
Good (i)	Mean Difference (ij): 5.86Standard Error: 0.51p < 0.001	Mean Difference (ij): 3.56Standard Error: 0.44p < 0.001	NA	Mean Difference (ij): 0.53Standard Error: 0.86p = 0.926
Very good (i)	Mean Difference (ij): 5.33Standard Error: 0.90p < 0.001	Mean Difference (ij): 2.83Standard Error: 0.86p = 0.026	Mean Difference (ij): −0.53Standard Error: 0.86p = 0.926	NA

NA Not applicable; the Games-Howell test was applied when variance homogeneity was violated.
Bold indicates statistically significant comparisons.

The association between scale-based FDI knowledge scores and participants' age and work experience was evaluated. Both age (Spearman's rho = 0.354) and years of professional experience (Spearman's rho = 0.419) demonstrated a positive correlation with knowledge scores ($p < 0.001$).

Agreement between participants' self-perceived FDI knowledge and actual scores was assessed, showing a slight concordance ($\kappa = 0.150$, $SE = 0.033$, $t(354) = 5.328$, $p < 0.001$) [11]. Crosstab data are presented in **Table 4**.

Table 4. Distribution of participants' self-perceived FDI knowledge across scale-based scores

Variables	Participants' Self-Perception of FDI Knowledge	Scale-Based FDI Knowledge Scores				Total
		Very good, n (%)	Good, n (%)	Intermediate, n (%)	Low, n (%)	
Low	n (%)	6 (6.82)	38 (23.90)	33 (40.74)	19 (67.86)	96
Intermediate	n (%)	36 (40.91)	80 (50.31)	45 (55.56)	9 (32.14)	170
Good	n (%)	42 (47.73)	34 (21.38)	3 (3.70)	0 (0)	79
Very good	n (%)	4 (4.55)	7 (4.40)	0 (0)	0 (0)	11
Total		88	159	81	28	356

Chi-square testing could not be applied because 25% of the cells had expected counts below 5.

The effect of FDI training on senior pharmacy students' knowledge scores was assessed by comparing pre-training and post-training scores to determine short- and long-term outcomes. Of 95 senior students, 75 attended all sessions and were included in the analysis. Before the training, the mean score was 8.85 ± 3.57 ($N = 75$), which significantly increased to 16.24 ± 3.15 immediately post-training ($p < 0.001$). The magnitude of this improvement was large, with Cohen's $d = 1.95$ (95% CI 1.556–2.328; paired correlation = 0.368; $p < 0.001$). Eight weeks after training, the mean score slightly rose to 16.67 ± 2.59 ($N = 75$), with no significant difference compared to the

immediate post-training score ($p = 0.307$). Repeated measures ANOVA indicated significant differences across time points ($F = 218.18$, $p < 0.001$), and paired-sample t-tests confirmed substantial gains from pre-training to both short- and long-term assessments ($p < 0.001$), while short-term versus long-term differences were non-significant ($p = 0.307$).

Binary logistic regression was performed to identify predictors of achieving good or very good scale-based FDI knowledge scores. The model included age, work experience, sex, current pharmacy practice area, education level, and self-perceived FDI knowledge. The overall model was significant ($\chi^2(14) = 128.11$, $p < 0.001$), explaining 42.7% of variance, and correctly classified 78.9% of participants. Goodness-of-fit testing indicated no evidence of poor fit ($\chi^2(8) = 3.32$, $p > 0.05$). Among individual predictors, female sex (OR = 1.842; 95% CI 1.027–3.302) and high self-rated FDI knowledge (OR = 18.311; 95% CI 4.879–68.718) were significantly associated with higher odds of achieving good or very good scores ($p < 0.05$).

Sex-specific analyses were conducted, showing that being female increased the likelihood of achieving good or very good scores by 1.842-fold. Results are detailed in **Table 5**.

Table 5. Comparison of participant-related variables by sex

Factors	Female (N = 234)	Male (N = 122)	Cramer's V (95% CI)	p-value
Age, years	26.00 [24.00–30.00]	26.50 [24.00–32.00]	–	0.085*
Working experience, years	2.00 [0.00–5.00]	2.00 [0.00–8.00]	–	0.714*
Willingness to attend FDI training in the future	–	0.182**	–	–
Yes, n (%)	203 (86.75)	97 (79.51)	–	–
No, n (%)	7 (2.99)	7 (5.74)	–	–
Not sure, n (%)	24 (10.26)	18 (14.75)	–	–
Self-perception of FDI knowledge	–	0.596**	–	–
Low, n (%)	58 (24.79)	38 (31.15)	–	–
Intermediate, n (%)	114 (48.72)	56 (45.90)	–	–
Good, n (%)	55 (23.50)	24 (19.67)	–	–
Very good, n (%)	7 (2.99)	4 (3.28)	–	–
Frequency of being counseled on FDIs	–	0.253*** (0.161–0.356)	< 0.001**	–
Never, n (%)	9 (3.85)	6 (4.92)	–	–
Seldom, n (%)	71 (30.34)	65 (53.28)	–	–
Sometimes, n (%)	97 (41.45)	40 (32.79)	–	–
Often, n (%)	57 (24.36)	11 (9.02)	–	–
Current education level	–	0.297**	–	–
Senior student, n (%)	56 (23.93)	39 (31.97)	–	–
Bachelor's degree, n (%)	117 (50.00)	59 (48.36)	–	–
Master's/doctoral degree or in continuum, n (%)	39 (16.67)	17 (13.93)	–	–
Specialty in pharmacy or in continuum, n (%)	22 (9.40)	7 (5.74)	–	–
Current pharmacy field	–	0.207**	–	–
Community pharmacy, n (%)	62 (26.50)	41 (33.61)	–	–
Senior student, n (%)	56 (23.93)	39 (31.97)	–	–
Hospital pharmacy, n (%)	65 (27.78)	25 (20.49)	–	–
Specialty in pharmacy, n (%)	20 (8.55)	6 (4.92)	–	–
Academy, n (%)	16 (6.84)	5 (4.10)	–	–
Others, n (%)	15 (6.41)	6 (4.92)	–	–
University type for Bachelor's degree	–	0.938**	–	–

Government, n (%)	224 (95.73)	117 (95.90)	–	–
Private, n (%)	10 (4.27)	5 (4.10)	–	–
Receiving regular drug treatment	–	0.208**	–	–
Yes, n (%)				

* Mann-Whitney U test
** Chi-square test
*** Cramer's V (95% CI estimated via 1,000 bootstrap samples)
Bold values indicate statistical significance.

Table 5 demonstrates that sex was significantly associated with counseling frequency on FDIs, with a moderate effect size, suggesting that the observed differences are meaningful in practice, not only statistically significant.

While numerous tools exist to detect and manage drug-drug interactions, identifying food-drug interactions (FDIs) remains considerably more challenging. This difficulty largely stems from incomplete documentation of patients' dietary habits and limited professional knowledge regarding these interactions. FDIs are particularly critical because they can trigger various health complications, especially in older adults [12]. The complexity of FDIs increases further when patients with multiple comorbidities concurrently use several medications and dietary supplements, raising the risk of adverse events [13].

It is crucial to recognize that certain medications carry a higher likelihood of FDI, making it important to inform both patients and their caregivers about potential risks. The sources consulted for FDI information vary widely. A large-scale study found that the internet was the most frequently used source (63.0%), followed by physicians (50.9%) and pharmacists (38.5%). The study also reported that individuals who rely on non-scientific sources tend to have lower FDI knowledge than those consulting scientific resources [14]. Among students, nutrition science and pharmacy students most commonly referred to scientific articles and the Ministry of Health, respectively [15, 16]. In Poland, over 25% of medical students indicated that the patient information leaflet was their primary source of FDI information [7]. In the present study, package inserts were the most frequently utilized resource among pharmacists. Collectively, these findings suggest that healthcare professionals tend to consult scientific sources, while non-health professionals more often rely on non-scientific references. Scientific sources provide reliable, evidence-based information, whereas non-scientific sources are prone to inaccuracies, misinformation, or unverified claims, emphasizing the critical role of HCPs in providing accurate guidance.

Prior research has demonstrated that being female significantly increases the likelihood of having higher FDI knowledge [14]. Consistently, our study found that female participants were 1.842 times more likely to achieve good or very good scale-based FDI knowledge scores. This contrasts with earlier studies reporting no significant relationship between sex and FDI knowledge [17–20]. One possible explanation is that females in our sample were consulted more frequently about FDIs, thereby enhancing their knowledge through repeated exposure and additional self-directed research. Supporting this, **Table 1** shows that mean knowledge scores increase as the frequency of counseling on FDIs rises, providing a rationale for why female participants demonstrated higher knowledge scores.

Although age and work experience were positively correlated with scale-based FDI knowledge in Spearman correlation analyses, these factors did not retain statistical significance in the logistic regression model. This may reflect the presence of stronger predictors in the model, such as self-perceived FDI knowledge and sex. Additionally, the likely correlation between age and work experience could reduce their independent contribution, highlighting that age or experience alone may be insufficient to predict knowledge levels, with other professional and individual factors playing more prominent roles. Prior studies also indicate that age, years of experience, and years since graduation significantly influence pharmacists' FDI knowledge and awareness [19]. Another study reported that participants older than 25 years had a greater understanding of FDIs and specific food-drug interactions [20]. In line with these findings, our data showed that pharmacists' scale-based FDI knowledge scores increased with age and work experience, likely reflecting greater exposure to FDIs and increased ability to recognize potential interactions over time. Nonetheless, these correlations should be

interpreted cautiously, as correlation does not establish causation.

This study evaluated pharmacists' FDI knowledge levels. Multiple studies have documented insufficient knowledge among healthcare professionals regarding FDIs [20–22]. A 2021 study reported that over half of HCPs scored below average on FDI knowledge assessments, with pharmacists performing best among doctors, nurses, and dietitians [18]. Other studies indicate that pharmacists and those with over five years of experience demonstrate significantly higher FDI knowledge [17, 20]. Pharmacists are uniquely positioned to prevent FDIs by educating patients and other HCPs, though knowledge gaps still exist among some professionals.

In addition, we examined the association between participants' university type for their bachelor's degree and regular medication use with scale-based FDI knowledge levels across subgroups. No statistically significant differences were identified. This lack of significance may be due to small effect sizes as well as variability in the number of participants across the subgroups.

Participants' current educational attainment was found to influence their FDI knowledge. Prior studies reported that individuals with master's or doctoral degrees were more likely to demonstrate high levels of FDI knowledge [14, 23]. Consistent with these findings, participants holding postgraduate qualifications scored the highest across all knowledge domains [20]. In a separate study, hospital pharmacists were 4.37 times more likely to display a positive attitude toward FDIs compared with other pharmacists, which was attributed to their frequent engagement with complex, multimorbid patients and the counseling they provide [24]. In our research, the group with the highest knowledge levels consisted of pharmacists who had completed a 3-year specialty training post-graduation. This suggests that advanced training in pharmacy significantly enhances FDI knowledge. Although hospital and community pharmacists interact regularly with patients, those with a specialty in pharmacy appear more thorough regarding FDIs due to the provision of comprehensive pharmaceutical care. Therefore, pharmacists in other practice settings should be prioritized for targeted FDI training.

Evidence indicates that patients often rely on HCPs for FDI information, and reporting potential FDIs to healthcare professionals is essential [25]. This underscores the importance of HCPs possessing adequate knowledge and providing appropriate counseling to patients. In our study, participants who perceived their FDI knowledge as good were 18.311 times more likely to achieve good or very good scores on the FDI knowledge scale. Previous research has highlighted insufficient FDI knowledge among undergraduate students, who generally prefer dedicated FDI instruction rather than brief mentions in broader courses [7, 15, 16]. Providing FDI as a separate course at the undergraduate level significantly improves knowledge acquisition. Multiple studies have confirmed that FDI-focused training leads to substantial knowledge gains [22, 26]. In one study involving pharmacy students, post-training evaluations indicated that participants felt more confident and better prepared to advise patients on FDIs [27].

In our investigation, senior pharmacy students showed a significant increase in knowledge after the training. However, it should be noted that factors beyond the training itself—such as prior exposure through elective courses, seminars, congresses, individual interest, or additional self-directed learning—may have contributed to this improvement. Furthermore, completing the pre-test may have helped students identify knowledge gaps, increasing focus during the training session. The lack of a significant difference between short-term and long-term post-training scores suggests that the effects of the training were sustained over time.

To improve pharmacists' FDI knowledge, we recommend incorporating an FDI course into the pharmacy curriculum. Embedding FDI content as dedicated modules, using interactive methods such as case-based learning and role-playing, and employing vertical integration across academic years could strengthen knowledge retention and practical skills. Additionally, assessments that evaluate both factual understanding and clinical reasoning would better prepare students for real-world practice. Continuing professional development opportunities on FDIs post-graduation could further enhance pharmacists' competencies. Supporting this, a study involving nurses who received training and informational leaflets from clinical pharmacists reported a significant reduction in incorrect drug administration and FDI events [28]. Enhanced pharmacist knowledge emphasizes their potential role in educating other HCPs about FDIs. Overall, there remains a shortage of structured education and training programs addressing clinically relevant FDIs for pharmacists and other healthcare professionals [29].

This research has several inherent limitations. First, the data were collected through a self-administered online questionnaire, which may have introduced biases such as participants providing socially desirable answers or inaccuracies due to recall errors. Second, the study was conducted at a single university in Türkiye, limiting the extent to which the results can be generalized to other academic settings, both within the country and internationally. Additionally, the use of convenience sampling means that the sample may not fully reflect the broader population, and selection bias could have occurred because participants were chosen based on accessibility rather than through randomization. Despite these constraints, the findings highlight the need to strengthen pharmacists' awareness of FDIs to better support public health initiatives.

Conclusion

This study successfully applied the Turkish FDI Knowledge Scale to both licensed pharmacists working in diverse practice environments in Türkiye and senior pharmacy students from a single university. Results demonstrated variation in FDI knowledge across participant groups. Pharmacists who had completed a specialty in pharmacy program achieved the highest mean scores (17.00 ± 2.73), whereas senior pharmacy students had the lowest (9.23 ± 3.78). Female participants were more likely than males to attain good or very good FDI knowledge (OR 1.842; 95% CI 1.027–3.302), which appears to reflect their higher frequency of providing counseling on FDIs. Participants' own assessment of their FDI knowledge strongly predicted performance, with those reporting a good understanding being 18.311 times more likely to achieve high scores (95% CI 4.879–68.718).

The study also showed that structured training significantly enhanced FDI knowledge among senior pharmacy students, with improvements persisting over time (pre-training: 8.85 ± 3.57; post-training short-term: 16.24 ± 3.15; post-training long-term: 16.67 ± 2.59). These findings support the recommendation to incorporate dedicated FDI education into the pharmacy undergraduate curriculum and to offer continuing professional development opportunities for practicing pharmacists. Such measures could increase pharmacists' confidence and engagement in providing FDI counseling in routine practice.

Future research should aim to replicate these findings across multiple universities and diverse cultural and educational contexts, both nationally and internationally, as the single-institution design of the current study limits its generalizability. Conducting multi-center or cross-country studies could yield stronger evidence on the effectiveness of educational interventions, guiding the development of standardized, globally applicable pharmacy curricula addressing FDIs.

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