Original Article

# Knowledge of Physicians about Pharmacokinetics Services in Saudi Arabia

**Mohamed S. Imam[1,2,*], Yousef Ahmed Alomi[3], Randa M. Abdel-Sattar[4], Yara Abdulrahman S. Alangari[5], Renad Abdulrhman A. Alotaibi[5]**

[1]Pharmacy Practice Department, College of Pharmacy, Shaqra University, Shaqra 11961, Saudi Arabia.

[2]Clinical Pharmacy Department, National Cancer Institute, Cairo University, Egypt.

[3]BSc. Pharm, MSc. Clin Pharm, BCPS, BCNSP, DiBA, CDE, Critical Care Clinical Pharmacists, TPN Clinical Pharmacist, Freelancer Business Planner, Content Editor and Data Analyst, Riyadh, Saudi Arabia.

[4]Biomedical Sciences Department, College of Pharmacy, Shaqra University, Shaqra 11961, Saudi Arabia.

[5]Pharm D, College of Pharmacy, Shaqra University, Saudi Arabia.

***Address for Correspondence: Mohamed S. Imam**

**Pharmacy Practice Department, College of Pharmacy, Shaqra University, Shaqra 11961, Saudi Arabia.**

**Email: Imammohamed311@gmail.com**

**DOI:** 10.47750/pnr.2022.13.S07.052

## Abstract

Objective: In this study, we aimed to assess the knowledge of pharmacokinetics in the Kingdom of Saudi Arabia.

Methods: This is a cross-sectional survey conducted to assess the knowledge of physicians about the pharmacokinetics services in Saudi Arabia. It is a self-reported questionnaire distributed in an electronic format to various physicians, including from interns to consultants and specialists in the Kingdom of Saudi Arabia. The survey collected demographic information of the responders and their knowledge of selected pharmacokinetics elements in medical care such as resources of knowledge of pharmacokinetics elements in medical practice. We used 5-point Likert response scale system with close-ended questions to obtain responses. The data were collected through the Survey Monkey system and analyzed using various software such as Statistical Package of Social Sciences (SPSS), Jeffery's Amazing Statistics Program (JASP), and Microsoft Excel (version 16).

Results: A total of 259 physicians responded to the questionnaire. Of them, 107 (44.96%) were male and 131 (55.04%) were female responders, with non-statistically significant difference between them (p=0.120). Most of the responders were in the age group of 36–45 years (91 (37.30%)) and 46–55 years (85 (34.84%)), with statistically significant differences between all age groups (p=0.000). Most of the physicians were residents (74 (29.48%)), followed by specialists (69 (27.49%)) and interns (68 (27.09%)), with statistically significant differences between them (p=0.010). The average score was 3.50 for physician's knowledge of pharmacokinetics services, with high scores obtained for the element knowledge of the concept of pharmacokinetics (4.12), the concept of therapeutic drug monitoring (3.67), and official standardized form for requesting pharmacokinetics services or drug levels (3.61), with non-statistically significant differences between the responses (p=0.313). Most of the resources used for pharmacokinetic services by physicians were drug information resources (e.g., Micromedex, Lexicomp, and Epocrates; 128 (52.24%), and medical association literature/guidelines/recommendations (63 (25.71%)). We performed single test of reliability analysis using McDonald's ω (0.897) and Cronbach's α (0.8878).

Conclusion: The knowledge of physicians about pharmacokinetics services was found to be inadequate in the Kingdom of Saudi Arabia. Therefore, targeting undergraduate and postgraduates training and education of physicians about pharmacokinetics is highly recommended to improve clinical outcome of patients and to avoid unnecessary economic burden on the healthcare system in the Kingdom of Saudi Arabia.

**Keywords**: Pharmacokinetics, Knowledge, Physicians, Saudi Arabia.

## INTRODUCTION

Over the past few years, many medications have been introduced in the local as well as in the international market. Each medication has its unique pharmacokinetic properties, such as drug absorption, drug distribution, and excretion via kidney or liver [1,2]. Some medications can be found in specific levels in the blood [2,3], and if the level exceeds the upper limit, then it possible that adverse events or toxicity occur [1,3]. On the contrary, if the drug level decreases below the lower limit, then then positive effect of medication will not be accomplished. These medications are called narrow therapeutic index medications [1-

3]. They need specific calculation for dosing requirements and establishment of proper drug levels in the blood. Furthermore, calculations should be performed for such medications to know the half-life and the time to reach a steady-state level in blood [2,4]. Moreover, these medications have a particular time of drug administration and the appropriate time to withdraw samples for testing [2]. Therefore, a detailed comprehensive pharmacokinetic information of the drug in question is highly important to any healthcare professional, including physicians. Previous studies have been conducted to analyze the misuse of drug levels and special pharmacokinetic services to be implemented [5,6]. Other studies have focused their research on the impact of pharmacokinetics education on healthcare professionals and about the economic implications of pharmacokinetics services [7-9]. Moreover, some studies have reported the use of therapeutic drug monitoring services by nurses [10,11]. So far, it is not easy to find a physician with the knowledge of pharmacokinetics services. To the best of our knowledge, there are only a few studies conducted to assess the knowledge of physicians about their perception of pharmacokinetics services in the Kingdom of Saudi Arabia or Middle Eastern countries [4,12]. Therefore, in this study, we aimed to assess the knowledge of physicians about pharmacokinetics services in the Kingdom of Saudi Arabia.

## Methods

This is a 6-month cross-sectional study conducted to assess the knowledge of physicians about pharmacokinetics services in Saudi Arabia. It is a self-reported electronic survey questionnaire and was distributed to physicians from interns to consultants and specialists in Saudi Arabia. All non-physicians, students, and incomplete surveys were excluded from the study. The survey collected demographic information of the responders and their knowledge of some of the selected pharmacokinetics elements in medical care. We also collected information about various resources available on pharmacokinetics aspects in medical care. We used 5-point Likert response scale system with close-ended questions to obtain responses. Based on the previous literature with unlimited population size, the sample size was calculated with the following parameters: the confidence level was 95%, with a z score of 1.96 and margin of error of 5–6.5%, population percentage of 50%, and a drop-out rate of 10%. As a result, the sample size was calculated as 251–432 with a power of study of 80% [13-15]. The response rate required for the calculated sample size was at least 60–70% [15,16]. The survey was distributed in an electronic format through various social media such as Telegram and through face-to-face contact. A reminder message was sent once every 1-2 weeks. The survey responses were validated by expert reviewers and pilot testing. Moreover, various tests to assess reliability were conducted such as McDonald's $\omega$, Cronbach's $\alpha$, Gutmann's $\lambda 2$, and Gutmann's $\lambda 6$. The data were collected through the Survey Monkey system and analyzed with Microsoft Excel (version 16), Statistical Package of Social Sciences (SPSS), and Jeffery's Amazing Statistics Program (JASP) software. We performed descriptive and frequency analysis, goodness of fit, correlation analysis, and inferential analysis to determine factors affecting the knowledge of physicians about pharmacokinetics services and medication safety. The STROBE (Strengthening the reporting of observational studies in epidemiology statement: guidelines for reporting observational studies) guided the reporting of the results of this study [17,18].

## Ethical Approval

The research protocol was approved by research ethics committee, Pharmacy College, Shaqra University, Saudi Arabia.

## Results

A total of 259 physicians responded to the survey questionnaire, with most of them coming from the southern region (98 (39.36%)) and worked at university hospitals (47(18.15%)) and national guard hospitals (39 (15.06%)), with statistically significant differences between the areas (p=0.000). Of them, 107 (44.96%) were male and 131 (55.04%) were female, with non-statistically significant differences between them (p=0.120). Most of the responders were in the age group of 36–45 years (91 (37.30%)) and 46–55 years (85 (34.84%)), with statistically significant differences between all age groups (p=0.000). Most of the physicians were residents (74 (29.48%)), followed by specialists (69 (27.49%)) and interns (68 (27.09%)), with statistically significant differences between them (p=0.010). Most of the responders were holding supervisor jobs (96 (39.51%)) and physician staff (67(27.57%)), with statistically significant differences between them (p=0.000). Most of the physicians had a work experience of more than 4 years (197 (80.08%)) with nearly half of them of the medical, surgical, and emergency physicians 148 (57.14%) with statistically significant between them (p=0.000) (Tables 1 and 2). The average score for knowledge of physicians about pharmacokinetics services was 3.50, with the highest scores obtained for the element's knowledge of the concept of pharmacokinetics (4.12), the concept of therapeutic drug monitoring (3.67), and official standardized form for requesting pharmacokinetics services or drug levels (3.61), and the responses did not show any statistically significant differences (p=0.313). In contrast, the element the time for the requested drug level (3.28) did not show any statistically significant differences between the responses (p=0.313). The element cost of drug level analysis (3.35) showed statistically significant differences between the responses (p=0.012). However, all aspects showed statistically significant

differences between the responses ($p<0.05$) except one only (Table 3). Most of the resources used for pharmacokinetics services by physicians were drug information resources (e.g., Micromedex, Lexicomp, and Epocrates; 128 (52.24%)), medical association literature/guidelines/recommendations (63 (25.71%)), followed by the Internet (e.g., Google and WebMD; 46 (18.78%)), and drug labeling (31 (12.65%)) (Table 4). The scores obtained for single-test reliability analysis for McDonald's ω was 0.897, Cronbach's α was 0.8878, Gutmann's λ2 was 0.882, and Gutmann's λ6 was 0.914.

Table 1: Demographic, social information

| Locations | Response Count | Response Percent | p-value (X2) |
|---|---|---|---|
| Central area | 41 | 16.47% | 0.000 |
| North area | 49 | 19.68% | |
| South area | 98 | 39.36% | |
| East area | 49 | 19.68% | |
| West area | 12 | 4.82% | |
| Answered question | **249** | | |
| Skipped question | **10** | | |
| Site of work | Response Count | Response Percent | p-value (X2) |
| MOH Hospitals | 15 | 5.79% | 0.000 |
| Military hospitals | 23 | 8.88% | |
| National Guard Hospital | 39 | 15.06% | |
| Security forces hospitals | 35 | 13.51% | |
| University hospital | 47 | 18.15% | |
| MOH primary care centres | 28 | 10.81% | |
| Private hospitals | 37 | 14.29% | |
| Private ambulatory care clinics | 23 | 8.88% | |
| Private primary healthcare centre | 12 | 4.63% | |
| Answered question | **259** | | |
| Skipped question | **0** | | |
| Gender | Response Count | Response Percent | p-value (X2) |
| Male | 107 | 44.96% | 0.120 |
| Female | 131 | 55.04% | |
| Answered question | **238** | | |
| Skipped question | **21** | | |
| Age | Response Count | Response Percent | p-value (X2) |
| 24–35 | 47 | 19.26% | 0.000 |
| 36–45 | 91 | 37.30% | |
| 46–55 | 85 | 34.84% | |
| > 55 | 21 | 8.61% | |
| Answered question | **244** | | |
| Skipped question | **15** | | |

Table 2: Demographic, social information

| Physicians Qualifications | Response Count | Response Percent | p-value (X2) |
|---|---|---|---|
| Intern | 68 | 27.09% | 0.010 |
| Resident | 74 | 29.48% | |
| Specialist | 69 | 27.49% | |
| Consultant | 40 | 15.94% | |

| | | | |
|---|---|---|---|
| Answered question | **251** | | |
| Skipped question | **8** | | |
| Position Held | Response Count | Response Percent | |
| Director of medical departments | 28 | 11.52% | 0.000 |
| Assistant director of the medical department | 52 | 21.40% | |
| Supervisor | 96 | 39.51% | |
| Physician staff | 67 | 27.57% | |
| Intern | **243** | 11.52% | |
| Answered question | **16** | | |
| Skipped question | 28 | | |
| Years of experience | Response Count | Response Percent | |
| Less than one year | 13 | 5.28% | 0.000 |
| 1-3 | 36 | 14.63% | |
| 4-6 | 83 | 33.74% | |
| 7-9 | 63 | 25.61% | |
| 10-12 | 42 | 17.07% | |
| > 12 years | 9 | 3.66% | |
| Answered question | **246** | | |
| Skipped question | **13** | | |
| Physicians Specialties | Response Count | Response Percent | |
| Critical Care | 21 | 8.54% | 0.000 |
| Emergency | 40 | 16.26% | |
| Medical | 61 | 24.80% | |
| Surgical | 47 | 19.11% | |
| Paediatrics | 35 | 14.23% | |
| Anaesthesia | 12 | 4.88% | |
| Psychiatry | 14 | 5.69% | |
| Obstetrics and Gynaecology | 12 | 4.88% | |
| Family medicine | 4 | 1.63% | |
| Answered question | **246** | | |
| Skipped question | **13** | | |

Table 3: Pharmacokinetics services assessment of knowledge

| | **Complete knowledge** | | **Incomplete knowledge** | | **Partial knowledge** | | **Little knowledge** | | **No knowledge** | | **Total** | **Weighted Average** | **p-value** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1- Have you ever heard about the concept of Pharmacokinetics (drug levels)?** | 56.67% | 136 | 12.92% | 31 | 18.33% | 44 | 10.00% | 24 | 2.08% | 5 | 240 | 4.12 | 0.000 |
| **2- Have you ever heard about the concept of therapeutic drug monitoring?** | 32.03% | 49 | 22.88% | 35 | 28.10% | 43 | 13.73% | 21 | 3.27% | 5 | 153 | 3.67 | 0.000 |
| **3- Have you ever receive course/attended a workshop about Pharmacokinetics** | 27.27% | 39 | 23.78% | 34 | 31.47% | 45 | 13.29% | 19 | 4.20% | 6 | 143 | 3.57 | 0.000 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **services or therapeutic drug monitoring?** | | | | | | | | | | | | | |
| **4- In Saudi Arabia, are there legal provisions in the medicines act that provide for Pharmacokinetics activities.** | 25.58% | 33 | 20.93% | 27 | 29.46% | 38 | 19.38% | 25 | 4.65% | 6 | 129 | 3.43 | 0.000 |
| **5- In Saudi Arabia, is there a Pharmacokinetics services?** | 25.21% | 30 | 22.69% | 27 | 29.41% | 35 | 15.13% | 18 | 7.56% | 9 | 119 | 3.43 | 0.001 |
| **6- In Saudi Arabia, is there an official standardized form for requesting Pharmacokinetics services or drug levels?** | 27.97% | 33 | 27.97% | 33 | 24.58% | 29 | 16.10% | 19 | 3.39% | 4 | 118 | 3.61 | 0.000 |
| **7- Do you know from where you can get the Pharmacokinetics services or drug level form?** | 25.42% | 30 | 27.12% | 32 | 25.42% | 30 | 16.95% | 20 | 5.08% | 6 | 118 | 3.51 | 0.000 |
| **8- Do you know what is the time within which you should request a drug level?** | 26.42% | 28 | 20.75% | 22 | 20.75% | 22 | 18.87% | 20 | 13.21% | 14 | 106 | 3.28 | 0.313 |
| **9- Do you know the estimating drug dosing interval?** | 26.37% | 24 | 23.08% | 21 | 28.57% | 26 | 16.48% | 15 | 5.49% | 5 | 91 | 3.48 | 0.003 |
| **10- Do you know the estimating medication half-life?** | 20.95% | 22 | 28.57% | 30 | 27.62% | 29 | 16.19% | 17 | 6.67% | 7 | 105 | 3.41 | 0.002 |
| **11- Do you know the time need to reach drug level steady-state levels?** | 26.92% | 28 | 25.00% | 26 | 25.00% | 26 | 16.35% | 17 | 6.73% | 7 | 104 | 3.49 | 0.005 |
| **12- Do you know the dose calculation in renal failure?** | 25.00% | 22 | 22.73% | 20 | 25.00% | 22 | 19.32% | 17 | 7.95% | 7 | 88 | 3.38 | 0.063 |
| **13- Do you know the dose calculation in hepatic failure?** | 25.51% | 25 | 21.43% | 21 | 28.57% | 28 | 19.39% | 19 | 5.10% | 5 | 98 | 3.43 | 0.003 |
| **14- Do you know the dose calculation in obese patients?** | 22.22% | 22 | 31.31% | 31 | 21.21% | 21 | 19.19% | 19 | 6.06% | 6 | 99 | 3.44 | 0.003 |
| **15- Do you know the drug interaction that's an increase or decrease blood drug levels?** | 23.47% | 23 | 27.55% | 27 | 27.55% | 27 | 16.33% | 16 | 5.10% | 5 | 98 | 3.48 | 0.001 |
| **16- Do you know the cost of** | 20.88% | 19 | 25.27% | 23 | 28.57% | 26 | 18.68% | 17 | 6.59% | 6 | 91 | 3.35 | 0.012 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **drug level analysis?** | | | | | | | | | | | | | |
| **Answered** | | | | | | | | | | | **259** | | |
| **Skipped** | | | | | | | | | | | **0** | | |

Table 4: The most resources used for Pharmacokinetics services

| Answer Choices | Responses | |
|---|---|---|
| Scientific literature | 7 | 2.86% |
| Peer discussions | 21 | 8.57% |
| Medical association literature/guidelines/recommendations | 63 | 25.71% |
| Internet (e.g., Google searches, WebMD, etc) | 46 | 18.78% |
| Drug labelling | 31 | 12.65% |
| Laboratory director/personnel | 16 | 6.53% |
| SFDA website | 24 | 9.80% |
| None of the above, have not consulted any source | 16 | 6.53% |
| Drug information resources (Micromedex, Lexicomp, Epocrates, ...) | 128 | 52.24% |
| **Answered** | **245** | |
| **Skipped** | **14** | |

Table 5. Factors (average scores) influencing the Pharmacokinetics services assessment of knowledge

| | | Pharmacokinetics services assessment of knowledge | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Factors** | **N** | **Average scores** | **Std. D** | **Median** | **Lower Bound** | **Upper Bound** | **P-value** |
| **Region** | Central | 36 | 2.4868* | .88727 | 2.6771 | 2.1866 | 2.7870 | 0.001 |
| | North | 47 | 2.2582 | .99617 | 2.3125 | 1.9658 | 2.5507 | |
| | South | 82 | 1.8780 | .95312 | 1.5833 | 1.6686 | 2.0874 | |
| | East | 45 | 1.7488 | .86624 | 1.3333 | 1.4885 | 2.0090 | |
| | West | 10 | 1.5750 | .89258 | 1.0000 | .9365 | 2.2135 | |
| | Total | 220 | | | | | | |
| **Site of works** | MOH Hospitals | 12 | 2.0856 | 1.01280 | 2.0000 | 1.4421 | 2.7292 | 0.577 |
| | Military hospitals | 20 | 1.7128 | .82808 | 1.3750 | 1.3252 | 2.1003 | |
| | National Guard Hospital | 35 | 2.0618 | .99338 | 2.0769 | 1.7205 | 2.4030 | |
| | Security forces hospitals | 30 | 2.0079 | 1.08758 | 1.6875 | 1.6018 | 2.4140 | |
| | University hospital | 41 | 2.0188 | .99773 | 1.9375 | 1.7038 | 2.3337 | |
| | MOH primary care centres | 25 | 2.1577 | .95503 | 2.0625 | 1.7635 | 2.5519 | |
| | Private hospitals | 30 | 2.1068 | .96886 | 2.0000 | 1.7451 | 2.4686 | |
| | Private ambulatory care clinics | 18 | 1.8158 | .80301 | 1.5962 | 1.4164 | 2.2151 | |
| | Private primary healthcare centre | 9 | 2.2023 | 1.03760 | 2.9333 | 1.4047 | 2.9999 | |
| | Total | 220 | | | | | | |
| **Age** | 24–35 | 38 | 2.4110* | .95891 | 2.4063 | 2.0958 | 2.7262 | 0.037 |
| | 36–45 | 86 | 2.0276 | .97180 | 2.0000 | 1.8192 | 2.2359 | |
| | 46–55 | 78 | 1.8758* | .95224 | 1.4500 | 1.6611 | 2.0905 | |
| | > 55 | 18 | 1.7667 | .83032 | 1.5833 | 1.3538 | 2.1796 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | 220 | | | | | | |
| **Gender** | Male | 101 | 2.0478 | .96729 | 2.0000 | 1.8569 | 2.2388 | 0.933 |
| | Female | 119 | 1.9939 | .96858 | 1.8125 | 1.8181 | 2.1697 | |
| | Total | 220 | | | | | | |
| **Physician Qualification** | Intern | 55 | 2.4546* | .86377 | 2.5625 | 2.2211 | 2.6881 | 0.000 |
| | Resident | 67 | 2.0872 | .95337 | 2.1667 | 1.8547 | 2.3198 | |
| | Specialist | 62 | 1.6465 | .94382 | 1.0000 | 1.4068 | 1.8862 | |
| | Consultant | 36 | 1.8659* | .91984 | 1.3542 | 1.5547 | 2.1772 | |
| | Total | 220 | | | | | | |
| **Physician specialties** | Critical Care | 18 | 2.4089 | 1.00137 | 2.5313 | 1.9109 | 2.9068 | 0.093 |
| | Emergency | 35 | 2.0614 | 1.9901 | 2.1875 | 1.7308 | 2.3921 | |
| | Medical | 57 | 1.9690 | 1.00221 | 1.7500 | 1.7031 | 2.2349 | |
| | Surgical | 41 | 1.7065 | .92120 | 1.2500 | 1.4157 | 1.9973 | |
| | Paediatrics | 33 | 1.9408 | .97236 | 1.5000 | 1.5960 | 2.2855 | |
| | Anaesthesia | 10 | 2.1889 | .97056 | 2.5500 | 1.4946 | 2.8832 | |
| | Psychiatry | 13 | 2.3753 | 1.00413 | 2.7000 | 1.7685 | 2.9820 | |
| | Obstetrics and Gynaecology | 10 | 2.1475 | .62687 | 2.2917 | 1.6991 | 2.5960 | |
| | Family medicine | 3 | 2.7024 | .57825 | 2.8571 | 1.2659 | 4.1388 | |
| | Total | 220 | | | | | | |
| **Position** | Director of medical departments | 24 | 2.4334 | 1.10931 | 2.4148 | 1.9650 | 2.9019 | 0.042 |
| | Assistant director of the medical department | 47 | 2.0354 | .96559 | 2.0000 | 1.7519 | 2.3189 | |
| | Medical Director | 86 | 1.8445* | .93431 | 1.3875 | 1.6441 | 2.0448 | |
| | Physician staff | 63 | 2.0859 | .91578 | 2.0000 | 1.8553 | 2.3166 | |
| | Total | 220 | | | | | | |
| **Experiences** | <1 | 11 | 2.7286 | .70939 | 2.5000 | 2.2520 | 3.2052 | 0.000 |
| | 1-3 | 34 | 2.5018 | .86467 | 2.5938 | 2.2001 | 2.8035 | |
| | 4-6 | 75 | 2.0310 | 1.03828 | 1.7500 | 1.7921 | 2.2699 | |
| | 7-9 | 60 | 1.7289* | .81576 | 1.4500 | 1.5182 | 1.9396 | |
| | 10-12 | 33 | 1.6414* | .89872 | 1.0000 | 1.3227 | 1.9600 | |
| | >12 | 7 | 2.6864 | .76242 | 2.6923 | 1.9813 | 3.3915 | |
| | Total | 220 | | | | | | |

Table 6: Multiple regression of Factors with the Physician's Knowledge of Pharmacokinetics services [a]

| Model | | | | | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | 95.0% Confidence Interval for B | | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | R | R Square | F | Sig. | B | Std. Error | Beta | | | Lower Bound | Upper Bound | Tolerance | VIF |
| 1 | (Constant) | .392 [b] | .154 | 4.790 | .000[b] | 3.375 | 0.370 | | 9.127 | 0.000 | 2.646 | 4.104 | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location | | | | | -0.167 | 0.062 | -0.189 | -2.677 | 0.008 | -0.290 | -0.044 | 0.802 | 1.246 |
| | Site of work | | | | | 0.047 | 0.030 | 0.104 | 1.565 | 0.119 | -0.012 | 0.107 | 0.906 | 1.104 |
| | Age (years) | | | | | -0.083 | 0.077 | -0.074 | -1.076 | 0.283 | -0.236 | 0.069 | 0.846 | 1.182 |
| | Physician gender | | | | | -0.039 | 0.125 | -0.020 | -0.313 | 0.755 | -0.286 | 0.207 | 0.959 | 1.043 |
| | Physician Qualifications | | | | | -0.148 | 0.064 | -0.158 | -2.315 | 0.022 | -0.274 | -0.022 | 0.861 | 1.162 |
| | Physician Specialties | | | | | 0.011 | 0.034 | 0.022 | 0.339 | 0.735 | -0.055 | 0.078 | 0.919 | 1.088 |
| | Current Position | | | | | -0.062 | 0.066 | -0.062 | -0.951 | 0.343 | -0.192 | 0.067 | 0.944 | 1.059 |
| | Years of experiences | | | | | -0.113 | 0.059 | -0.136 | -1.925 | 0.056 | -0.229 | 0.003 | 0.801 | 1.248 |

[a]: Dependent Variable: Physician's Knowledge of Pharmacokinetics services, Predictors [b]: (Constant), Location, Site of work, Age (years), Physician gender, Physician Qualifications, Physician Specialties, and Your Current Position

**Bootstrap for Coefficients**

| Model | | B | Bootstrap[a] | | | | |
|---|---|---|---|---|---|---|---|
| | | | Bias | Std. Error | Sig. (2-tailed) | 95% Confidence Interval | |
| | | | | | | Lower | Upper |
| 1 | (Constant) | 3.375 | 0.011 | 0.370 | 0.001 | 2.655 | 4.148 |
| | Location | -0.167 | - 0.001 | 0.060 | 0.006 | -0.285 | -0.044 |
| | Site of work | 0.047 | 0.001 | 0.029 | 0.105 | -0.010 | 0.109 |
| | Age (years) | -0.083 | - 0.003 | 0.075 | 0.263 | -0.237 | 0.063 |
| | Physician gender | -0.039 | -8.736E-05 | 0.122 | 0.735 | -0.278 | 0.212 |
| | Physician Qualifications | -0.148 | -0.002 | 0.067 | 0.027 | -0.277 | -0.020 |
| | Physician Specialties | 0.011 | -0.001 | 0.033 | 0.748 | -0.050 | 0.073 |
| | Current Position | -0.062 | 0.001 | 0.068 | 0.369 | -0.198 | 0.074 |
| | Years of experiences | -0.113 | 3.504E-05 | 0.060 | 0.059 | -0.233 | 0.003 |

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

Factors influencing the physician's knowledge of pharmacokinetics services

There are various factors that might affect the knowledge of physicians about pharmacokinetics services. Using the independent samples Kruskal–Wallis test and the Bonferroni correction for multiple tests with adjusted significant values, we obtained the following results: some factors such as worksite, gender, and specialty did not affect the knowledge of physicians about pharmacokinetics services, and there was no statically significant differences between them ($p>0.05$). However, with the highest scores (2.4868), five locations affected knowledge of physicians about pharmacokinetics services, with statistically significant differences between them ($p=0.001$). Different age groups revealed different scores about physician's knowledge of pharmacokinetics services, with the highest average score (2.4110) obtained for the age group 24–35 years, with statistically significant differences between all age groups ($p=0.037$). Qualification of physician affected their knowledge of pharmacokinetics services, with interns scoring the highest average score (2.4546), and there were statistically significant differences between all groups of qualifications ($p=0.000$). Position held by the physician also affected their knowledge of pharmacokinetics services, with the lowest average score (1.8445) obtained for the position of medical director, with statistically significant differences between all positions held ($p=0.042$). Number of years of work experience also affected the knowledge of physicians about pharmacokinetics services, with the lowest average score (1.7289) obtained for 7–9 years of work experience and 10–12 years of work experience (1.6414), with statistically significant differences between them ($p=0.000$) (Table 5).

The association between the physician's knowledge of pharmacokinetics services and factors affected it included the location, worksite, age (years), gender, qualification, specialty, years of experience in the medical career, and position held. In multiple regression analysis, we used physician's knowledge of pharmacokinetics services as the dependent variable and the factors affecting it as the expletory variable. There was a weak association ($R=0.392$ with $p=0.000$) between physician's knowledge of pharmacokinetics services and factors it. Most of the factors showed non-significant differences ($p>0.05$). However, there were only two factors which explained the variation: location explained 18.9% of the negative association and qualification explained 15.8% of the negative association, with the variation in the physician's knowledge of pharmacokinetics with a statistically significant differences between them ($p=0.008$ and $p=0.022$, respectively). The association was verified by the non-existence of multi-collinearity with the location as the Variance Inflation Factor (VIF=1.246), qualification with VIF=1.162 were less than three or five [19-21] (Table 6).

## Discussion

Pharmacokinetics knowledge is critical for some medications. For instance, some medications have a narrow therapeutic index [1,3]. Such medications require a specific level in the blood to produce the therapeutic effect [1]. Furthermore, if the drug level is above a particular limit, then it can cause severe adverse effects [1,3]. Some of the adverse drug reactions are irreversible, for example aminoglycoside causes ototoxicity [3]. Therefore, it is important that the physician has the knowledge of drug distribution and its blood level by calculating the dose required based on kidney or hepatic function. The pharmacokinetics knowledge of physicians in Saudi Arabia is not extensive [4,12]. Therefore, in this study, we aimed to assess the pharmacokinetics knowledge of physicians. We used a validated questionnaire with convenient sampling techniques to obtain responses of the physicians. However, we did not obtain an optimal sample size. Most of the responders were from the southern region belonging to various university of non-Ministry of Health governmental sectors, which might be because of the origin of data collectors. Both male and female responders did not show significant differences. Most of the responders were middle-aged with appropriate years of work experience, qualification, specialization, and position held in medical practice, which is like previous studies [4,12].

In this study, the knowledge of pharmacokinetics services by physician was found to be inadequate, which is like a previous study [4] but contrary to the other [12]. This might be because of a different study location that had proper implementation of pharmacokinetics services. Sometimes there was no or weak implementation of pharmacokinetics services [4,12]. However, clinicians were given the concept of pharmacokinetics and monitoring of drug therapy. Furthermore, the standard form for knowing the pharmacokinetic component exists, and physicians attended courses like previous studies [4,12]. This means that the physician is familiar with the pharmacokinetics ordering a form of drug level. Moreover, pharmacokinetics educational courses are currently available to the physicians. However, the element when to request a drug level or cost of analysis of drug levels obtained lowest score, which has not been reported in previous studies [4,12]. This proves the lack of knowledge of physicians about pharmacokinetics services. Moreover, the physicians were not familiar with the cost of pharmacokinetic services. This shows the malpractice of pharmacokinetics services and incorrect choice of appropriate time for the test. In addition, the knowledge of physicians about the calculation of doses for renal and hepatic failure was found to be insufficient. Moreover, the knowledge of physicians about the estimated half-life of the drug in question was not sufficient.

Most of the responders referred to various drug information resources and medical literature from various medical association [4], followed by internet and drug labeling. This shows that the physicians more frequently used drug information textbooks or contacted drug information center. In addition, they used evidence-based literature for pharmacokinetics knowledge. The internet and drug labeling were the third and fourth resources used by the physicians in case when there was no information available in the first two references. Finally, the drug information resources at healthcare organizations were considered as the primary resources. This shows that there was some level of collaboration between the physicians and pharmacists but was not optimum, or to some level, the pharmacists provided pharmacokinetics services as reported in a previous study [11].

Most of the factors did not affect the pharmacokinetics knowledge of the physician such as worksite, gender, specialty, and position held in medical practice; however, some factors had some effect such as geographic location, with the central region revealing higher knowledge score than that of the other regions. This result is expected because most of the expert hospitals and healthcare facilities are located in the central region. In addition, the age factor had an effect on pharmacokinetics knowledge, wherein the physicians in the age group of 24–35 years had the lowest knowledge followed by interns, residents, and specialists. According to a previous study, younger age correlated with more knowledge of some pharmacokinetics elements [4]. Furthermore, higher qualification revealed inadequate knowledge of pharmacokinetics, which can be explained by the age factor. On the contrary, similar to a previous study, in this study, younger generation (interns) had more knowledge than those who had higher qualification [4]. This result was expected because of the fact that recent graduates from medical school have latest information. In summary, location was a dependent factor which increased the knowledge of physicians about pharmacokinetics services, whereas higher qualification reduced the pharmacokinetics knowledge of physicians.

## Limitation

The results of this study were highly informative about the actual knowledge of physicians about the pharmacokinetic services provided in Saudi Arabia. However, there were some limitations such as the unequal geographic distribution of the responders, worksite, age, qualification, position held, and number of years of work experience. Finally, the sample size of this study did not reach the optimal level. Therefore, we recommend future studies with equal demographic information.

## Conclusion

In summary, the knowledge of physicians about pharmacokinetics services was found to be inadequate in Saudi Arabia. However, the physicians were familiar with the basic information of pharmacokinetics terms. However, their knowledge about some practical pharmacokinetics services was inadequate. Most of the demographic factors had an influence their knowledge; however, young age and intern responders knew more than others. The collaboration between the physicians and pharmacists in providing pharmacokinetics services is not clear yet. We strongly recommend more educational courses to be delivered to the physicians regarding pharmacokinetics services and that pharmacists and physicians should collaborate with other healthcare professionals, including nurses, in order to provide better pharmacokinetics services.

## Acknowledgement:

The authors would like to thank the Deanship of Scientific Research at Shaqra University for supporting this work.

## Conflict of interest:

The authors declare no conflicts of interest.

## Funding:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Consent for publications:

Informed consent was obtained from all the participants

## REFERENCES

1. Ghiculesco R. Abnormal laboratory results: Therapeutic drug monitoring: which drugs, why, when, and how to do it. Aust Prescr. 2008;31(2):42–4.
2. McInnes G. The value of therapeutic drug monitoring to the practicing physician- a hypothesis in need of testing. Br J Clin Pharmacol. 1989;27(3):281–4.
3. Sayers J, Friedman M. How clinicians use therapeutic drug monitoring. Lab Med. 1997;28(8):524–8.
4. Alrabiah Z, Alwhaibi A, Alsanea S, Alanazi FK, Abou-Auda HS. A national survey of attitudes and practices of physicians relating to therapeutic drug monitoring and clinical pharmacokinetic service: strategies for enhancing patient's care in Saudi Arabia. Int J Gen Med. 2021;14:1513–24.

5. Jannuzzi G, Cian P, Fattore C, Gatti G, Bartoli A, Monaco F, et al. A multicenter randomized controlled trial on the clinical impact of therapeutic drug monitoring in patients with newly diagnosed epilepsy. Epilepsia. 2000;41(2):222–30.
6. Ye ZK, Tang HL, Zhai S Di. Benefits of Therapeutic Drug Monitoring of Vancomycin: A Systematic Review and Meta-Analysis. PLoS One. 2013;8(10).
7. Destache CJ. Economic Aspects of Pharmacokinetic Services. PharmacoEconomics [Internet]. 1993 Jun [cited 2018 Aug 28];3(6):433–6. Available from: http://link.springer.com/10.2165/00019053-199303060-00002
8. Urquhart J. Role of Patient Compliance in Clinical Pharmacokinetics: A Review of Recent Research [Internet]. Vol. 27, Clinical Pharmacokinetics. Springer International Publishing; 1994 [cited 2018 Aug 28]. p. 202–15. Available from: http://link.springer.com/10.2165/00003088-199427030-00004
9. Welty TE, Copa AK. Impact of vancomycin TDM inpatient care. 1994;28:1335–9.
10. Rajaduraivelpandian PB, Udaykumar P. A cross-sectional knowledge attitude practice study on therapeutic drug monitoring among health care professionals in a tertiary care hospital. Int J Basic Clin Pharmacol. 2020;9(6):879.
11. Almohammde S, Alhodian H, Almofareh S, Alshehri S, Almasri DM, Ghoneim RH. A survey of therapeutic drug monitoring in a teaching hospital. Saudi J Biol Sci [Internet]. 2021;28(1):744–7. Available from: https://doi.org/10.1016/j.sjbs.2020.11.002
12. Elmorsy E, Alriwely NS, Alruwaili ASM, Alanazi TSN, Alshemmari MNO. Knowledge and attitude towards therapeutic drug monitoring practices among physicians in Arar, Saudi Arabia. Pakistan J Med Heal Sci. 2020;14(3):1026–30.
13. Charan J, Biswas T. How to calculate sample size for different study designs in medical research? Vol. 35, Indian Journal of Psychological Medicine. 2013. p. 121–6.
14. Pourhoseingholi MA, Vahedi M, Rahimzadeh M. Sample size calculation in medical studies. Gastroenterol Hepatol from Bed to Bench. 2013;6(1):14–7.
15. G.Ezhumalai. How big a sample do I need require. Ann SBV. 2017;6(1):39–41.
16. Johnson TP, Wislar JS. Response rates and nonresponse errors in surveys [Internet]. Vol. 307, JAMA - Journal of the American Medical Association. 2012. p. 1805–6. Available from: http://www.aapor.org/Standard_Definitions2.htm.
17. Erik von Elm, Douglas G. Altman, Matthias Egger, Stuart J. Pocock, Peter C. Gøtzsche JPV. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies. PLoS Med [Internet]. 2007;4(10):1623–7. Available from: http://www.epidem.com/
18. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies [Internet]. Vol. 370, www.thelancet.com. 2007. Available from: www.plosmedicine.org
19. Liao D, Valliant R. Variance inflation factors in the analysis of complex survey data. Surv Methodol. 2012;38(1):53–62.
20. Akinwande MO, Dikko HG, Samson A. Variance Inflation Factor: As a Condition for the Inclusion of Suppressor Variable(s) in Regression Analysis. Open J Stat. 2015;05(07):754–67.
21. Thompson CG, Kim RS, Aloe AM, Becker BJ. Extracting the Variance Inflation Factor and Other Multicollinearity Diagnostics from Typical Regression Results. Basic Appl Soc Psych. 2017;39(2):81–90.