OPEN ACCESS

Saudi Journal of Medicine
Abbreviated Key Title: Saudi J Med
ISSN 2518-3389 (Print) | ISSN 2518-3397 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Transforming Clinical Learning: Insights on Mobile Medical Imaging Applications Use among Undergraduate Students

Abbas Omer[1], Momen Abdou Alkhir[2], Mohamed Yousef[3], Mahmoud Abdel Hameed Shahin[4]*, Hanady Elyas Osman[3], Elbagir Hamza Manssor[5], Mogahid Mohammed Ahmed Zidan[6], Wafa Abbas[1], Kalid Hassan[3]

[1]Radiological Sciences Department, Alghad College for Applied Medical Sciences, Al-Madinah, Saudi Arabia
[2]Medical Technical College, Fezzan University, Murziq, Libya
[3]Radiological Sciences Program, Batterjee Medical College, Jeddah, Saudi Arabia
[4]Nursing Department, Prince Sultan Military College of Health Sciences, Dhahran, Saudi Arabia
[5]Department of Applied Radiologic Technology, College of Applied Medical Sciences, University of Jeddah, Jeddah, Saudi Arabia
[6]Faculty of Radiology and Nuclear Medicine Science, National Ribat University, Khartoum, Sudan

DOI: https://doi.org/10.36348/sjm.2026.v11i04.004 | **Received:** 21.02.2026 | **Accepted:** 15.04.2026 | **Published:** 20.04.2026

***Corresponding Author:** Mahmoud Abdel Hameed Shahin
Associate Professor of Medical-Surgical and Critical Care Nursing, Nursing Department, Prince Sultan Military College of Health Sciences, Dhahran, Eastern region, Saudi Arabia; Email- mshahein@psmchs.edu.sa, https://orcid.org/0000-0001-5145-3702

Abstract

Smartphone applications have significant benefits in various specialties. The medical field is no exception to this trend, but more research is needed on the use of smartphone medical imaging apps among Saudi Arabian students. This study aimed to evaluate the awareness of mobile radiology applications (Apps), and the effectiveness of mobile applications. The findings of the study are important to enhance the integration of mobile technological resources in the teaching-learning process of radiology which is still an unexplored issue. A descriptive, cross-sectional survey was conducted during January and February 2025. four hundred ninety participants, including undergraduate medical imaging students from governmental and private institutions across Saudi Arabia, participated in the study. Most of the undergraduate students agreed (40.7%) and strongly agreed (28.6%) that the mobile medical imaging Apps were easy, quick, well organized, and gained the confidence of the users. 50.5% of the participants used mobile apps during their daily clinical practice, and 42.9% agreed that mobile apps improved their practical skills. 33% of the participants reported that mobile medical imaging Apps were more effective than logbooks or pocketbooks, while 40.7% showed supplement logbooks or pocketbooks were more effective. The study found that participants who installed medical imaging apps had better knowledge and skills, particularly in practical skills (p-value = .017), radiographic positioning (p-value = .030), x-ray collimation (p-value < .001), radiographic anatomy (p-value < .001), and evaluating x-ray image criteria (p-value < .001), compared to those who did not install the apps. The findings of this study indicate that mobile medical imaging apps can enhance the practical skills and knowledge of radiology students. The positive outcomes observed suggest that these applications should be integrated into radiology curricula to provide students with accessible, efficient learning tools. Future research should investigate the long-term effects of mobile apps on clinical practice, as well as explore how their integration can be optimized across different educational settings.

Keywords: impact, medical imaging, mobile applications, clinical practice, radiographic positioning Apps, undergraduate students.

INTRODUCTION

Numerous apps and other online learning tools highlight various radiographic modalities and aspects of anatomy and disease. Both patients and physicians utilize medical mobile applications extensively in many different medical sectors [1]. Smartphone applications are software programs that can be installed on mobile devices. iPhone, Android, and Blackberry are the most popular smartphone operating systems, and each has its own app store where users can browse and download apps that interest them [2]. With the rapid growth of smartphone applications and the realization of the significant benefits of their use in various specialties, the medical field was no exception to this trend, as the increasing popularity of using applications resulted in the creation of a specific medical application category in the Apple App Store in 2008 [3].

Despite being a recent innovation, mobile health applications are seeing rapid growth, showing no signs of abating in the near future. Exceeding 259,000 health-related programs are accessible in app stores, such as Google Play and Apple's iOS App Store, for smartphone devices. As of early 2015, around 100,000 health applications have been introduced. Approximately 1,000 new applications are released to the market each month. These applications offer a multitude of features, from basic text message reminders to platforms intended for advanced disease diagnosis and management. The expansion of the mobile health market is directly linked to the rising utilization of these applications [4]. These apps are helpful in training healthcare employees and provide a simple way to complete various tasks [1, 5].

Medical Apps, which can be downloaded quickly into mobile devices, are becoming increasingly popular among medical students and young clinicians [6]. According to a recent poll conducted in the United Kingdom, 84 % of 361 medical students believe cell phones and related medical apps are useful in their education [7]. Based on current trends, it's realistic to believe that using smartphone Apps will help medical students prepare for their future clinical positions. As a result, many medical institutions have begun integrating this new technology into the classroom to provide a practical guide to future professionals [8, 9].

Current studies reported the growing warm reception of mobile applications in radiology education with regards to improving a student's confidence and skills as well as their learning experience. According to Picchiottino *et al.,* [10], and others in educational applications are being adopted more enthusiastically by medical students, especially radiology students, for their ease of use and effectiveness in supplementing traditional modes of learning. Such apps allow students to personalize their learning as they can easily obtain lectures, images, quizzes, and other relevant materials, all from the convenience of their mobile devices. The use of such technology in medical education promotes self-directed learning, which is an ongoing trend among students wishing to learn on their devices, as it caters to their needs as modern learners.

Medical imaging is no exception to the use of mobile apps as a sub-discipline of medicine, and the digital nature of radiology makes it ideally suited to smartphone applications [11, 12]. The expanding mobile application market has addressed the requirements of radiologists, resulting in numerous applications pertaining to diagnostic imaging. We can identify radiological image viewers (known as Digital Imaging and Communications in Medicine viewers), platforms for the exchange of images among physicians or medical institutions, protocols for proper patient positioning, guidelines from radiological scientific societies, applications for studying radiological anatomy, quizzes, and databases containing radiological questions [13].

According to Kim *et al.*, [14], the Apple App Store had 381 radiology-related apps in 2015. Radiology apps include teaching/learning, reference, viewing, information systems, and patient education apps. Even though apps have become increasingly popular in the field, medical imaging students have limited knowledge of how useful apps can be [14]. Medical students have always relied on textbooks as their primary source of information. However, as information technology has advanced, the number of students using mobile devices has expanded significantly [15, 16]. There is a substantial and unexplored body of literature regarding mobile device use and its effect on radiology education [17, 18]. However, to enhance the clarity of the relationships between mobile app usage, skill acquisition, and perceived outcomes, the authors of the current study added a diagram of a suggested conceptual framework that visually represents these relationships (Figure 1). The diagram illustrates the progression from mobile app usage to enhanced knowledge and skills, and how these, in turn, contribute to perceived improvements in clinical practice. Moreover, the awareness, attitude, and usability of medical apps that radiology students might use to further their medical education are highlighted in this study.

According to the literature analysis, there is limited research on the use of smartphones for Medical Imaging Apps among Saudi Arabian students [19], and integrating it in the radiology curricula considering more effective approaches is beneficial [20].

Even as mobile technologies permeate the healthcare educational system, very little has been done to assess the impact of radiographic positioning mobile applications on undergraduate medical imaging students. Most available works centered around generic medical education application do not interfocus on specialized imaging practices that are fundamental for radiology training. The uniqueness of this research is to focus on students' awareness, experiences, and perceptions of radiographic positioning applications critical for refined skill learning during clinical practice. This gap in the literature that informs how learning and confidence for procedural techniques are shaped with these applications is also examined in this study and serves to justify the need for mobile applications as additional educational resources in the radiology curriculum.

Although mobile apps have been widely studied in medical education globally, there is a lack of research on their use within Saudi radiology education. Previous studies have not adequately explored how these tools are perceived, their effectiveness in enhancing radiology students' skills, or their integration into the radiology curriculum in Saudi Arabia. This study aims to fill this gap by evaluating mobile radiology apps' impact on

medical imaging students' knowledge and practical abilities in the context of Saudi educational settings.

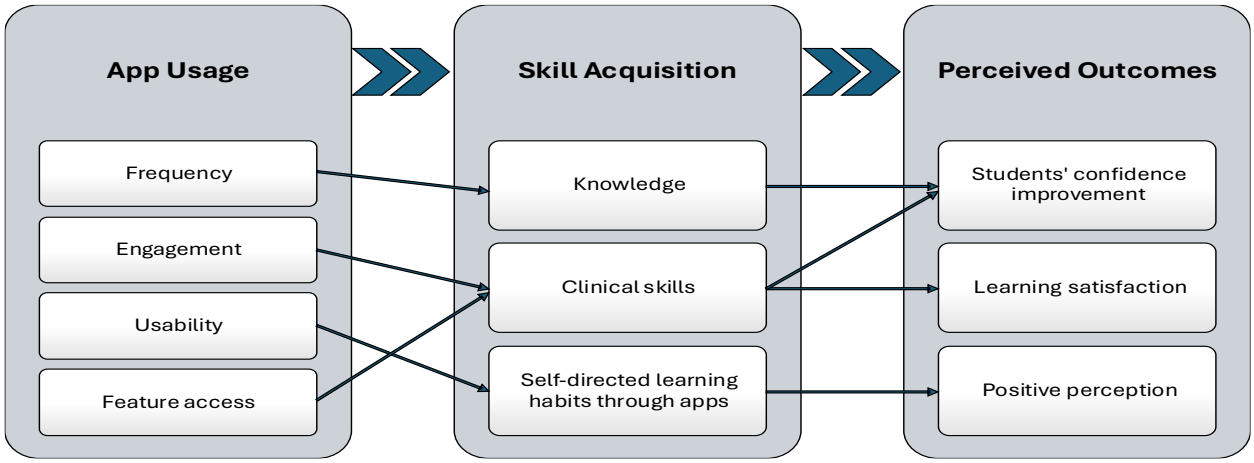

Figure 1: Conceptual framework illustrating the relationships between Apps usage components, skill acquisition, and perceived outcomes among radiology students. Frequent exposure to educational apps builds foundational knowledge over time, while high engagement enhances practical (clinical) skills. Usable and accessible applications foster independent, self-directed learning. Feature-rich applications simultaneously strengthen both theoretical understanding and practical competencies. As a result, greater knowledge acquisition boosts students' confidence, mastery of clinical skills leads to both improved confidence and learning satisfaction, and self-directed learning habits promote a more positive perception of their educational experiences

MATERIALS AND METHODS

Study design and participants

An online descriptive, cross-sectional survey was conducted during January and February 2025. The study included 490 medical imaging students. Its target group was undergraduate medical imaging students from different governmental and private educational institutions in Saudi Arabia. Inclusion criteria included undergraduate medical imaging students currently enrolled in governmental or private institutions in Saudi Arabia, with clinical exposure in radiology. Students who are in the first year of study or who have not yet participated in clinical training were excluded from the study.

Assumptions of the study:

- It is presumed that all participants responded to the questionnaire truthfully and to the best of their understanding.
- It is presumed that participants possessed equivalent access to mobile devices capable of executing medical imaging programs.
- It is presumed that the students' prior exposure to conventional educational resources (e.g., logbooks, guidebooks) was rather uniform among institutions.
- Participants were presumed to possess adequate foundational knowledge of radiographic positioning to assess the efficacy of the applications.
- Differences in participants' judgments are presumed to be predominantly shaped by their experience with mobile applications, rather than by extraneous influences.
- It is presumed that all suggested applications mentioned in the survey were operational and available to participants throughout their training time.

Sampling and sample size

In our investigation, we used the convenience sampling approach. Using the power analysis equation, the sample size was estimated using the Raosoft sample size calculator [21]. Sample sizes were determined based on the estimated target population to be at least 334 medical imaging students, with a 5% margin of error, a 95% confidence level, and a 50% response distribution (Figure 2). However, the final report included the participation of 490 medical imaging students from various universities around Saudi Arabia. The response rate was estimated as 78.51%, based on 490 completed the survey out of 624 eligible undergraduate medical imaging students across the regions of Saudi Arabia.

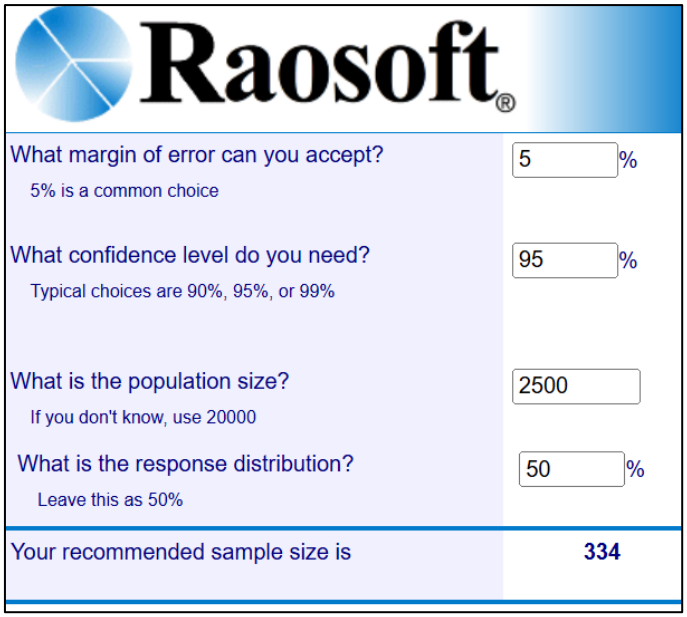

Figure 2: Sample size estimation

Data Collection Procedures and Tool

The researchers designed the data collection tool based on the study's aim and depending on the available literature [22-24]. The data for this study were collected using an electronic questionnaire adopting the Google Forms application, and the link was distributed across all medical imaging departments across the universities of Saudi Arabia via emails, WhatsApp groups, and telegram. From time to time, reminders were sent through the same media, which resulted in a greater response rate, reaching 490 medical imaging students. Each question in the questionnaire was revised by three specialists in radiology and medical imaging apps to ensure it was clear, comprehensive, and relevant. Some aspects were also updated based on their feedback. Two multilingual translators translated the questionnaire into Arabic, while two more translators translated the Arabic version back into English. Until a final version was decided upon, the revised English version was compared to the original. Each participant was allowed to select their preferred language, as the questionnaire was offered in both languages. To determine Cronbach's alpha for each questionnaire domain, we additionally carried out a pilot sample for the Arabic and English versions, resulting in a total of 40 responses that were not included in the final analysis. The Cronbach's alpha coefficient was calculated for all questionnaire domains, revealing an overall reliable tool at 0.813. The questionnaire consisted of four parts. The first part was related to participant's profile datasheet that contained gender, type of academic institution, and possession or non-possession of a medical application or reference guide. The second part was related to awareness of radiographic positioning Apps among medical imaging students. The third part covered the content and effectiveness of radiographic positioning Apps, and the fourth was their perception and satisfaction with medical applications.

The interval values for responses regarding awareness, experience, perception, and preference were established according to standards identified in educational research surveys and other studies examining technology adoption among students. Utilize explicit and unequivocal binary choices (Yes/No) to capture distinct awareness and usage behavior. A nuanced comprehension of students' perceptions. Responses like 'Superior to your prior knowledge' and 'Enhance your existing understanding' were designed to be more precise while without overwhelming participants with excessive choices. The proposed ranges must provide thorough insights while remaining convenient for responders to reduce survey fatigue. Furthermore, respondents were afforded the opportunity to express confusion (e.g., students had not utilized apps previously), with the option 'I'm not sure' included to promote integrity in data gathering. Through these measures, dependable interpretation of the data according to the study objectives was obtained.

The Advantages of the Method Used

The study used a mobile imaging applications awareness, experience, and perception questionnaire specifically designed for medical imaging students as a self-assessment test. This approach has multiple benefits: (1) It captures data from a larger sample at lower costs and within a shorter time frame; (2) It protects anonymity, which significantly reduces bias motivated by personal encounters and perceptions; (3) The overall design of the questionnaire made it possible to investigate many aspects (awareness, experience, perception, preferences) at once; (4) The closed-ended responses presented in the questionnaire ensured standardization that simplified statistical evaluation; and (5) The respondents' distinction as users and non-users of medical imaging applications enabled thorough contrasts of experiences among different students. This,

in particular, gave a wide-scope yet dependable understanding of what the current state of mobile application integration in teaching radiology is at.

Ethical Consideration

Ethical approval for the study was granted by The Research Ethics Committee at King Khalid University (HAPO-06-B-001), Kingdom of Saudi Arabia, with approval number ECM#2025-508 on March 6th, 2025. The study adhered to the ethical guidelines outlined in the Declaration of Helsinki, and informed consent was obtained from all participants before their involvement. All survey-related information was contained in the accompanying letter. As a result, it was assumed that they gave their informed permission by taking the survey and accepting it. Information about the participants was guaranteed to remain private. No personally identifiable information about specific subjects was included in the study.

Statistical Analysis

The statistical analysis was carried out using the Statistical Package for Social Sciences (SPSS) software version 30 for Windows. Categorical variables were provided as frequencies and percentages, whereas numerical values were presented as mean ± standard deviation (SD). Inferential analysis was used to investigate the various associations specified in the objectives. The chi-square test (χ^2) assessed the link between the dependent and independent variables. Moreover, *p-values* of less than 0.05 were considered significant.

RESULTS

Profile of the Participants

The researchers received 490 responses from the medical imaging students before embarking on data analysis. The first set of questions focused on the participants' profiles. As shown in Table 1, about one-third of respondents were male (307; 62.6%). A total of 365 participants (74.7%) reported having a medical imaging application, while 370 participants (75.8%) possessed a reference guidebook. Additionally, there were more participants from the private institution (333; 68.1%) compared to the public educational institution (157; 31.9%).

Table 1: Profile of the participants (N=490)

Parameters	Frequency	Percentage
Gender		
Male	307	62.60%
Female	183	37.40%
The type of academic institution		
Governmental institution	157	31.90%
Private institution	333	68.10%
Do you have medical imaging Apps installed on your smart device?		
Yes	365	74.70%
No	125	25.30%
Do you have a training logbook, pocketbook, or guideline reference book at the training site?		
Yes	370	75.80%
No	120	24.20%

Awareness Associated with a Radiographic Positioning Apps

The second set of questions focused on awareness of radiographic positioning apps, as presented in Table 2. A significant majority of students, 447 (91.2%), reported being aware of the existence of medical imaging apps. Among these, Navi radiography apps emerged as the most preferred option, favored by 46.2% of respondents. Additionally, 26.4% of the students reported that the teaching staff recommended using mobile medical imaging apps. Notably, 247 students (50.5%) utilized these apps during their clinical training.

Table 2: Awareness of radiographic positioning Apps (N=490)

Parameters	Frequency	Percentage
Interest in downloading radiographic positioning apps		
Yes	447	91.20%
No	43	8.80%
Commonly used radiographic positioning apps.		
Navi radiography	225	46.20%
iRadTech lite	11	2.20%
Anatomy and radiographic projections	54	11%
RX-Posiciones Radiologicas	32	6.60%
Others	43	8.80%

Parameters	Frequency	Percentage
I don't have any medical Apps	125	25.30%
Medical imaging apps were recommended by:		
Teaching staff	128	26.40%
Radiology department staff in the training site	49	9.90%
A colleague	54	11%
App Store	70	14.30%
Social media	43	8.80%
Website	11	2.20%
Others	11	2.20%
I don't have any medical Apps or not recommended to me	124	25.30%
Mobile medical imaging apps were used during clinical training.		
Yes	247	50.50%
No	243	49.50%

Effectiveness of mobile Apps: Information and skills provided for radiographic positioning

The third set focused on the effectiveness of the Apps content and related questions, which were derived from Bontrager's Textbook of Radiographic Positioning, the most commonly used radiography reference recommended by the Saudi Commission for Radiologic Technologists [25]. The results presented in Table 3A indicate that mobile applications aided the development of fundamental radiographic skills for medical imaging students. A large number of participants, 67%, stated that the mobile patient positioning apps furnished adequate and clear instructions. This number, though slightly lesser at 62.6%, also appreciated the apps for guiding the determination of X-ray beam alignment, center point, and angulation. Besides, 61.5% of students claimed that the apps provided clear indications of the anatomical structures that were drawn on the radiographs, and 59.3% of them claimed there was adequate guidance for the X-ray beam collimation technique. With respect to analyzing the criteria for evaluating the X-ray images, adequacy was claimed by 50.5% of respondents. It is important to point out that around a quarter of all the respondents for all skill areas was unsure, which was primarily explained by the respondents' inexperience with mobile medical imaging applications. All in all, the findings indicate that these mobile applications included the important skills needed for proper radiographic positioning.

The comparison of mobile applications to traditional educational resources, as illustrated in Table 3B, revealed that students' perceptions were predominantly positive. Approximately 29.7% of respondents indicated that the content of the mobile applications corresponded with the knowledge acquired in college, while 27.5% saw the applications as a beneficial supplement to their previous education. A mere 3.3% believed that the applications provided content entirely dissimilar to what was taught in college. Concerning practical convenience, 33.0% of students indicated that mobile applications were more user-friendly than traditional logbooks or pocketbooks, whilst 40.7% viewed the applications as supplementary to these conventional resources. A minor proportion (5.4%) regarded the applications as less effective, and 20.9% conveyed ambiguity due to insufficient exposure. These data indicate that mobile applications are often perceived more positively than traditional references due to their superior accessibility and usability.

Table 3A: Skills Provided by Mobile Applications for Radiographic Positioning (N=490)

Skill Area	Response	Frequency	Percentage
Necessary skills related to the patient's position	Enough and clear	328	67.00%
	Unclear	38	7.70%
	I'm not sure	124	25.30%
Necessary skills for X-ray beam alignment and angulation	Enough and clear	308	62.60%
	Unclear	58	12.10%
	I'm not sure	124	25.30%
Necessary skills related to radiographic anatomy	Anatomical parts indicated	301	61.50%
	Anatomical parts not indicated	65	13.20%
	I'm not sure	124	25.30%
Necessary skills related to X-ray collimation	Enough and clear	291	59.30%
	Unclear	75	15.40%
	I'm not sure	124	25.30%
Necessary skills related to evaluation criteria of X-ray images	Available	247	50.50%
	Not available	119	24.20%
	I'm not sure	124	25.30%

Table 3B: Perceived Effectiveness of Mobile Applications Compared to Traditional Resources (N=490)

Evaluation Area	Response	Frequency	Percentage
Compared to college learning content	Better than learned	70	14.3%
	Exactly like what learned	146	29.7%
	Completely different	16	3.3%
	Supplement learning	135	27.5%
	I'm not sure	124	25.3%
Compared to logbooks or pocketbooks	More effective and convenient	162	33.0%
	Supplement logbook or pocketbook	199	40.7%
	Less effective and convenient	26	5.4%
	I'm not sure	102	20.9%

The attitude of the students towards the usability of mobile medical imaging apps

The final set of questions was related to the attitude toward the usability and applicability of medical imaging apps, which was highly positive. Most students (70%) recommended choosing one application and integrating it as a clinical skills guideline tool in clinical practice in colleges and training sites (Figure 3). About half of the participants (48%) agreed and strongly agreed that medical imaging apps can replace textbooks/ pocketbooks/ logbooks.

Regarding the perspectives of medical imaging apps, most participants (72%) agreed that medical imaging applications are necessary tools for medical imaging students. More than two-thirds of the students (69%) agreed that medical imaging apps improved their practical skills.

More than half of the students agreed and strongly agreed that using mobile apps provides confidence in skills to their users (55%). Additionally, most of them agreed and strongly agreed that medical imaging app skills are well-organized (64%), quick to reach and apply practical skills (60%), and easy to use (62%).

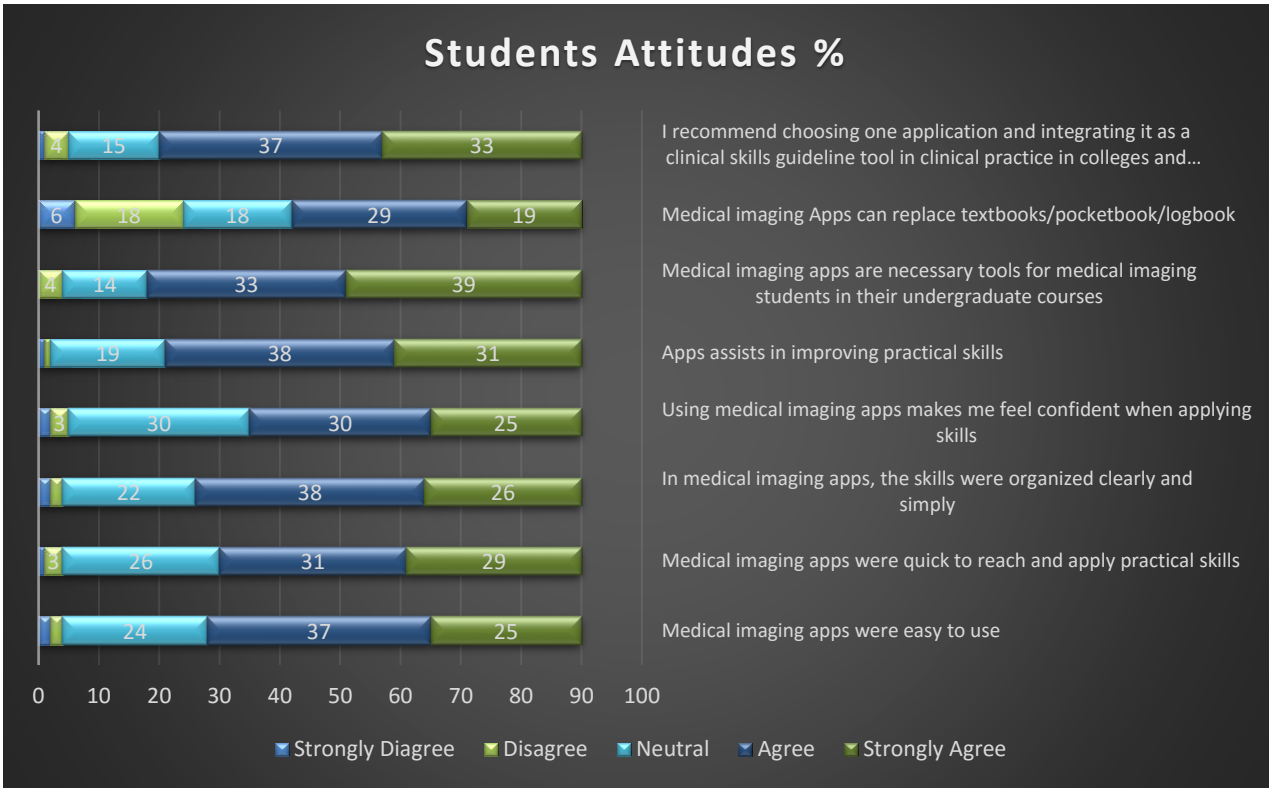

Figure 3: Students' attitude toward Apps (N=490)

Effect of having installed radiology mobile apps on students' knowledge and perceived skills of radiology mobile apps

The impact of having installed radiology mobile apps on the skills and knowledge of the participants is analyzed using chi-square in Table 4. It was shown that participants who installed the medical imaging apps had better knowledge and higher skills than those who did not. Participants who installed the radiology mobile apps reported significantly higher awareness of radiology

mobile apps (p-value < .001) and were significantly more interested in downloading radiographic positioning apps (p-value = .003). The students who installed the radiology mobile apps reported remarkably better skills related to radiographic anatomy, X-ray collimation, and the ability to evaluate the criteria of X-ray images (p-values < .001). Moreover, those who installed the radiology mobile apps had significantly greater perception that radiology mobile apps assist in improving practical skills compared to those who did not install the apps (p-value = .017).

The trends observed in the graphs reflect logical and educational realities associated with the integration of mobile technologies into medical imaging education. Higher levels of app usage among students can be attributed to the growing reliance on digital tools for practical training, especially where clinical logbooks and traditional materials may be insufficiently detailed or outdated. The preference for mobile applications over printed logbooks is physically significant because mobile apps provide real-time, accessible, and interactive content, aligning with the dynamic nature of clinical radiographic positioning, which demands immediate referencing and visual demonstrations. Similarly, the variation in confidence levels among app users versus non-users is significant, as immediate access to procedural demonstrations through apps can physically enhance psychomotor learning, skill acquisition, and memory reinforcement. These patterns demonstrate that mobile applications are not merely convenient but serve a critical educational function by bridging theoretical knowledge and hands-on clinical practice.

Table 4: The impact of having installed radiology mobile apps on students' knowledge and perceived skills of radiology mobile apps (N=490)

Variables	χ^2	Significance P-values
Previous awareness of radiology mobile apps	46.360	< .001**
Interest in downloading a radiographic positioning app	8.912	0.003**
Skills related to radiographic anatomy	45.819	< .001**
Skills related to X-ray collimation	54.901	< .001**
Skills related to the evaluation criteria of X-ray images	44.732	< .001**
Radiology mobile apps assist in improving practical skills	11.997	0.0170*

*** Highly significant at p < 0.01*
** Significant at p < 0.05*

The data in **Table 5** found that there were significant differences within the usage of the mobile application and its perceived effectiveness by gender. Specifically, male students used mobile devices more frequently than female students during their clinical training ($\chi^2 = 17.915$, $p < 0.001$), which points to greater use of digital resources by males in learning activities. In contrast, female students were more likely to agree that the use of mobile applications improved their practical skills ($\chi^2 = 13.084$, $p = 0.011$), which shows the overwhelming advantage mobile applications have in skill enhancement. In the case of confidence level after using the app, preference of mobile over manual tools, and considering the app's necessity to undergraduate courses for the level of education, the respondents were not significantly different by gender displaying uniform attitudes toward educational technology and mobile learning in those aspects.

Table 5. Association of gender with the study variables

Variable (significant gender)	χ^2	P-value
Used apps during clinical training (male)	17.915	.000 **
Confidence in clinical skills after app use	6.283	.179
Preference for mobile apps over traditional tools	1.632	.652
Perceived improvement in practical skills (female)	13.084	.011*
Necessity of mobile apps in undergraduate course	7.299	.063

**Significant at p < 0.05,*
***Highly significant at p < 0.01*

Analyzing the students from both governmental and private institutions revealed significant differences in perceptions and preferences (Table 6). Private institution students were considerably more positive regarding them strongly agreeing that mobile applications aided their practical skills ($\chi^2 = 18.067$, $p = 0.001$) and enhanced their clinical confidence ($\chi^2 = 39.796$, $p < 0.001$). This gap could stem from additional training or greater encouragement to utilize digital devices in private education settings. On the other hand, students from governmental institutions were significantly more likely to hold the view that they disagree with preference of mobile apps used as learning tools over conventional ones ($\chi^2 = 14.900$, $p = 0.002$), which suggests some tendency or inclination towards less mobile technology integration in these settings. The absence of mobile application necessity in undergraduate courses approached significance ($\chi^2 = 7.605$, $p = 0.055$),

demonstrating a gap in perceptions emerging, but not yet cohesive, across types of institutions.

Table 6: Association of academic institution with the study variables

Variable (significant institute)	χ^2	p-value
Used apps during clinical training	0.329	0.566
Confidence in clinical skills after app use (private)	39.796	.000 **
Preference for mobile apps over traditional tools (governmental)	14.900	.002*
Perceived improvement in practical skills(private)	18.067	.001*
Necessity of mobile apps in undergraduate course	7.605	.055

**Significant at p < 0.05, **Highly significant at p < 0.01*

The association between gender and the effectiveness of medical imaging applications as compared to other traditional tools are shown in Figure 4. The students' responses showed that there is an exceedingly significant association (P-value < .001), where male students are significantly more inclined to consider mobile applications useful relative to other materials like logbooks and pocketbooks. While both genders appreciated the educational functionalities of mobile applications, male students were more inclined toward their use than female students. This underscores the increasing evidence that there is a need to address the different strategies at the policy level to encourage the use of mobile apps for education in the clinical setting.

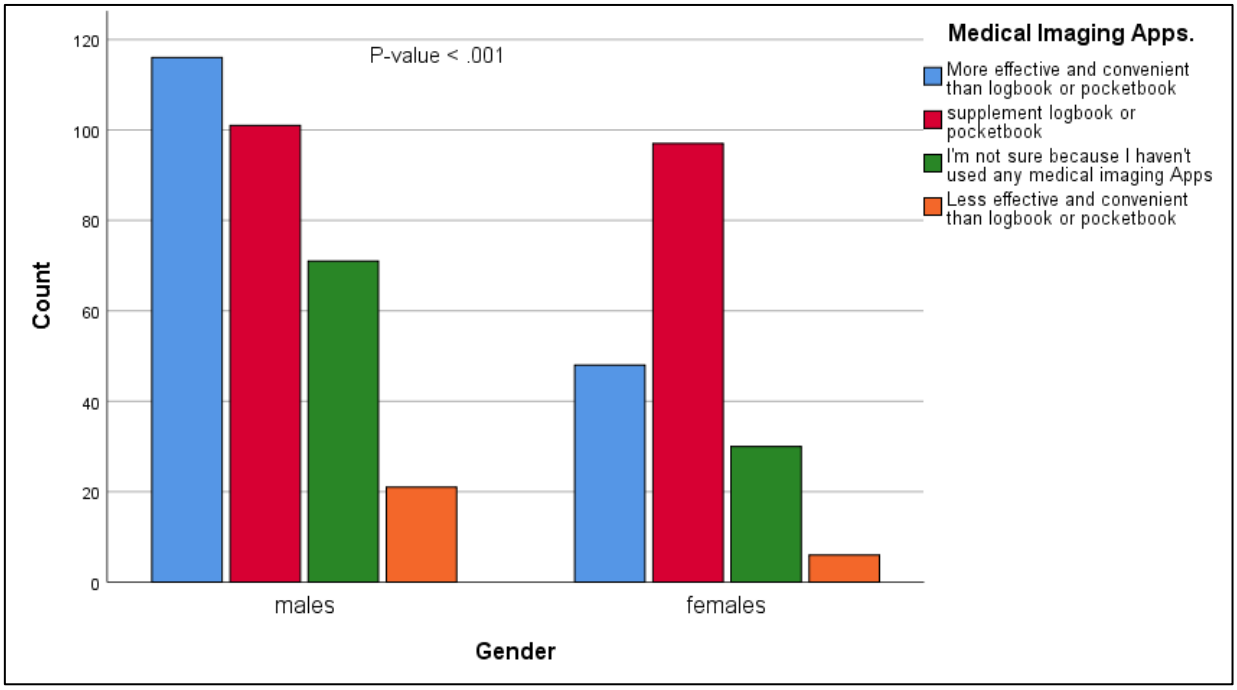

Figure 4: Association of gender with effective usage of medical imaging apps compared to traditional tools

DISCUSSION

The present study evaluated the impact of radiology mobile apps on the skills and knowledge of the participants who installed these applications on their mobiles or laptops. Many of the current applications and e-learning tools cover a variety of radiographic modalities, covering various aspects of anatomy and pathology. Many apps are designed for different training levels, allowing educators to select an appropriate resource for each trainee. The current study assessed the awareness of mobile radiology apps, the effectiveness of mobile applications in terms of knowledge and skills offered by mobile applications, and attitudes toward mobile radiology imaging Apps among medical imaging students.

In a previous study, it was found that the preferred applications in the field of medical imaging were imaging procedures, including X-ray procedures [26]. Another study found that radiology positioning Apps were among the most important applications for students [27]. With the support of these studies and since applications in terms of content need to be evaluated, as mentioned in a previous study [28], the current study evaluated the radiographic imaging procedures apps by comparing their content with Bontrager's Handbook of Radiographic Positioning and Techniques [25], taking critical elements on positioning and techniques. These elements include the patient's position, x-ray beam alignment, center point on the exposed organ, angulation of the X-ray tube, x-ray collimation, anatomical parts

indicated on the X-ray, and the evaluation criteria of X-ray images. It was found that male students utilized mobile devices more frequently than female students during their clinical training, indicating a higher engagement with digital resources in learning activities among males. Conversely, female students shown a greater propensity to concur that mobile applications enhanced their practical skills, indicating the significant advantage of mobile applications in skill development. These trends relating to gender agreed with the findings of Hisam *et al.*, [6] in the context of medical students, where male students were observed using mobile applications more frequently than their female counterparts, who believed more strongly in their educational utility. Some of these discrepancies could indicate varying and adapting pedagogical theories associated with learners' digital self-confidence, suggesting that male students have higher technological self-efficacy, and female students focus more on how education is enhanced. The analysis of such mobile learning disparities across broader contextual factors calls for a more equitable approach to integrating mobile learning.

Regarding the manual or handbook, the participants agreed that the App's contents were complementary to or superior to its content. In a similar study conducted in Saudi Arabia, medical students considered that medical applications complement books but preferred to gain knowledge from books [19]. Unlike studying in the United Kingdom, students preferred medical applications when attending clinical practice [15].

Regarding the comparison between private and governmental institutions, the study found private institution students were significantly more positive regarding the perception that mobile applications improved their practical skills and enhanced their clinical confidence. On the other hand, students from governmental institutions were significantly more likely to disagree with preference of mobile apps used as learning tools over conventional ones. Badiauzzaman [26] studied the use of mobile applications in medical imaging education in Malaysia. According to the findings, students from private colleges reported higher levels of involvement and positive perceptions of mobile applications in improving learning and clinical skill enhancement than their counterparts from public colleges. The authors provided an explanation as to why private faculty emphasized greater access, more positive promotional activities by the faculty, and better incorporation of mobile resources into the teaching framework.

In the present study, most of the participants' opinions were positive regarding the usability of the applications, as the majority agreed on their ease, quickness in finding information, and organization, which made them believe it improved their practical skills and increased their self-confidence. They also believed that it may replace handbooks. They recommended choosing reliable applications and integrating them into practical training. Medical imaging students in Malaysia gave the same impression about the usability of the applications [26]. While students showed adequate awareness of mobile medical imaging applications, the underutilization of these resources in clinical settings reported by only 50.5% of students poses several explanatory challenges. Institutional and clinical site policies might ban smartphones due to issues of professionalism, patient privacy, or distraction. Moreover, some clinical instructors might not actively endorse or may actively discourage the use of mobile devices during practical training which might lead students to disregard these resources. In addition, the varying levels of digital literacy, absence of unified institutional guidelines on which apps to use, and the prevailing attitude that traditional tools such as logbooks are sufficient may also help explain the stagnation in mobile apps usage in practice. This indicates the need for comprehensive policies and institutional initiatives that establish clear objectives within clinical education.

Different levels of mobile digital literacy among students can also impact the adoption and effective use of mobile medical imaging applications. Some learners are comfortable maneuvering around mobile devices, while others lack the exploration skills, or the confidence needed to harness the full benefits of mobile devices. This gap can create some level of incomplete participation and unequal educational results, especially if there is no proper guidance or support. Filling this gap through digital literacy education could ensure that mobile technology is effectively integrated into clinical education, making the learning environment more equitable.

In terms of the respondents' opinions about replacing handbooks, textbooks, and manuals with apps and integrating apps into clinical practice, previous studies contradict our present study's findings and attribute the reasons for the preference of medical books over medical apps to their ability to provide deeper comprehension and enhanced memory because handling papers can improve memorizing [15, 19, 25, 26, 28-30]. Several studies in Malaysia, the United Kingdom, and Australia agreed with the current study and reported that around two-thirds (68.9%) of students frequently used medical apps during clinical training [31, 32]. The results of this study correspond with earlier regional work done at King Abdulaziz University which also reported a high mobile medical application utilization rate amongst medical students [19]. In the same way, some other Gulf countries like the United Arab Emirates and Qatar have also shown that mobile app usage in medical education is prevalent and is appreciated by students due to the convenience, ease of use, and benefits the applications provide in the development of clinical skills. These observations add to the growing appreciation of mobile

applications as educational resources in the Gulf region, especially with the increase in their use in medical and radiology programs.

It was shown that the participants gained good knowledge and improved practice when they installed these medical apps. This finding is consistent with Badiauzzaman [26], who reported that most students (63.2%) were aware of the availability of medical imaging apps, and most students gave good feedback on the applications' perceptions and usage. Furthermore, research showed that students like apps and benefit from medical education. In a 2016 study, 731 medical students were polled; 90% agreed that medical apps improve practical knowledge, and 61% thought they were just as trustworthy as textbooks [33]. Research conducted the following year found no discernible difference between the benefits of ultrasound training guided by a mobile app and training guided by a textbook [34]. This suggests that mobile educational Apps are as beneficial and effective as textbooks.

While mobile applications offer clear advantages in terms of accessibility, interactivity, and real-time guidance, overreliance on these tools poses certain risks in professional practice. Traditional resources such as textbooks and logbooks often provide deeper theoretical context, comprehensive explanations, and are more aligned with structured curricula. Excessive dependence on apps may lead to superficial learning or neglect of critical reasoning, particularly in complex cases that require contextual judgment. Therefore, a balanced integration of mobile apps alongside traditional educational materials is essential to foster both practical competency and critical thinking in clinical radiography training.

CONCLUSION

The research highlights a high awareness and positive attitude among Saudi undergraduate students toward mobile medical imaging applications and usability, particularly in the context of radiographic positioning. A significant majority of students are aware of the existence of such apps, with Navi radiography apps being the most preferred. The majority agreed that it was easy to use, quick to discover information, and well-organized, which led them to improve their practical abilities and self-confidence. The findings indicated that mobile apps effectively enhanced practical skills in radiography, with a notable percentage of students acknowledging improvements in patient positioning skills and over half reporting better understanding in related areas like X-ray beam techniques and radiographic anatomy. Furthermore, students who installed and utilized mobile imaging applications demonstrated significantly higher knowledge and practical skills compared to those who did not.

Recommendations

To enhance medical education in radiography, it is essential to integrate mobile medical imaging applications into programs as standardized resources. Educators and clinical supervisors should actively demonstrate these tools during practical training to improve hands-on competencies. Establishing a core set of reliable mobile applications for use in teaching hospitals will enrich learning experiences. Additionally, organized orientation sessions should be implemented to boost students' digital literacy, ensuring they can effectively utilize these resources.

Institutions must develop guidelines that promote ethical mobile application use in clinical settings while safeguarding patient confidentiality. Consistent evaluation and feedback systems are needed to measure the educational impact of these applications, allowing for ongoing improvements. Finally, conducting longitudinal studies will provide insights into the long-term effects of mobile application use on clinical proficiency and professional development.

Limitations

The primary limitation of the current study was its reliance on cross-sectional research design. This approach restricted the depth of data exploration and prevented follow-up on participants' perceptions and attitudes over time or across different occasions.

The use of convenience sampling, which may affect the generalizability of the findings. Although the sample included participants from various institutions across Saudi Arabia, the results may not be representative of the entire population of radiology students, particularly those from institutions with different curricula or educational resources. Future longitudinal studies ought to focus on tracking the development of skills over time in students who use mobile apps, compared to those who rely on traditional resources.

Declarations

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of Interest: The authors declared that there was no conflict of interest.

Authors Contribution:

In this study, A. O. contributed to conceptualization and draft preparation. M. A. H. S. refining the manuscript, data analysis, and submitting the manuscript for publication. M. A. A. took charge of data curation and analysis, while M. Y. focused on software development and methodology validation. H. E. O. handled the literature review and initial drafting. E. H. M. managed project execution and visualization. M. M.

A. Z. was instrumental in data collection. W. A. assisted in drafting and editing, and K.H. took on supervisory roles and methodological validation. All authors have read and approved the final draft of the manuscript.

Funding Statement

No financial support was provided for the current research.

Ethical Consideration

Ethical approval for the study was granted by The Research Ethics Committee at King Khalid University (HAPO-06-B-001), Kingdom of Saudi Arabia, with approval number ECM#2025-508 on March 6th, 2025.

REFERENCES

1. Ventola CL. Mobile devices and apps for health care professionals: uses and benefits. *P t*. 2014;39(5):356-64.
2. Mcglaun S. Latest Nielsen Data Shows Smartphone Market Is Stabilizing, Major Os' Hold Steady: Slashgear; 2011 [11 February 2024]. Available from: https://www.slashgear.com/latest-nielsen-data-shows-smartphone-market-is-stabilizing-major-os-hold-steady-31155834/.
3. Dolan B. Timeline: Medical milestones for the iPhone South Korea: Mobilhealthnews; 2011 [12 June 2024]. Available from: https://www.mobihealthnews.com/11290/timeline-medical-milestones-for-the-iphone/.
4. Fougerouse PA, Yasini M, Marchand G, Aalami OO. A Cross-Sectional Study of Prominent US Mobile Health Applications: Evaluating the Current Landscape. *AMIA Annu Symp Proc*. 2017;2017:715-23.
5. Low D, Clark N, Soar J, Padkin A, Stoneham A, Perkins GD, et al. A randomised control trial to determine if use of the iResus© application on a smart phone improves the performance of an advanced life support provider in a simulated medical emergency. *Anaesthesia*. 2011;66(4):255-62 https://doi.org/10.1111/j.1365-2044.2011.06649.x.
6. Hisam A, Shafique MU, Khurshid MN, Hamza A, Asad MB, Shakeel T. Usage and types of mobile medical applications amongst medical students of Pakistan and its association with their academic performance. *Pak J Med Sci*. 2019;35(2):432-36 https://doi.org/10.12669/pjms.35.2.672.
7. Robinson T, Cronin T, Ibrahim H, Jinks M, Molitor T, Newman J, et al. Smartphone use and acceptability among clinical medical students: a questionnaire-based study. *J Med Syst*. 2013;37(3):9936 https://doi.org/10.1007/s10916-013-9936-5.
8. Mosa AS, Yoo I, Sheets L. A systematic review of healthcare applications for smartphones. *BMC Med Inform Decis Mak*. 2012;12:67 https://doi.org/10.1186/1472-6947-12-67.
9. Jeffries PR, Bushardt RL, DuBose-Morris R, Hood C, Kardong-Edgren S, Pintz C, et al. The Role of Technology in Health Professions Education During the COVID-19 Pandemic. *Acad Med*. 2022;97(3s):S104-s09 https://doi.org/10.1097/acm.0000000000004523.
10. Picchiottino P, Paignon A, Hesse L, Bos S, Wiesner Conti J, Schneider MP, et al. Large-scale, mobile and technology-enhanced serious game for interprofessional education: pilot study and lessons learnt. *J Interprof Care*. 2024;38(4):782-86 https://doi.org/10.1080/13561820.2024.2339291.
11. Huang CC, Lee PY, Chen PY, Liu TY. Design and implementation of a smartphone-based portable ultrasound pulsed-wave Doppler device for blood flow measurement. *IEEE Trans Ultrason Ferroelectr Freq Control*. 2012;59(1):182-8 https://doi.org/10.1109/tuffc.2012.2171.
12. European Society of R. ESR paper on the proper use of mobile devices in radiology. *Insights into Imaging*. 2018;9(2):247-51 https://doi.org/10.1007/s13244-017-0589-7.
13. Kufel J, Bargieł K, Koźlik M, Bartnikowska W, Janik M, Czogalik Ł, et al. Mobile applications in radiology: own study based on polish data. *Scientific Reports*. 2023;13(1):20049 https://doi.org/10.1038/s41598-023-46272-z.
14. Kim MS, Aro MR, Lage KJ, Ingalls KL, Sindhwani V, Markey MK. Exploring the Usability of Mobile Apps Supporting Radiologists' Training in Diagnostic Decision Making. *J Am Coll Radiol*. 2016;13(3):335-43 https://doi.org/10.1016/j.jacr.2015.07.021.
15. Koh KC, Wan JK, Selvanathan S, Vivekananda C, Lee GY, Ng CT. Medical students' perceptions regarding the impact of mobile medical applications on their clinical practice. *Journal of Mobile Technology in Medicine*. 2014;3(1):46-53 https://doi.org/10.7309/jmtm.3.1.7.
16. Eldeib A, Eldeib O, Mohammed A. Examining the Effectiveness of Educational Tools and Elements Used in Medical Textbooks: Students' Perspective. *Cureus*. 2024;16(4):e59264 https://doi.org/10.7759/cureus.59264.
17. Majumder MAA, Gaur U, Singh K, Kandamaran L, Gupta S, Haque M, et al. Impact of COVID-19 pandemic on radiology education, training, and practice: A narrative review. *World J Radiol*. 2021;13(11):354-70 https://doi.org/10.4329/wjr.v13.i11.354.
18. Alsoufi A, Alsuyihili A, Msherghi A, Elhadi A, Atiyah H, Ashini A, et al. Impact of the COVID-19 pandemic on medical education: Medical students' knowledge, attitudes, and practices regarding electronic learning. *PLoS One*. 2020;15(11):e0242905 https://doi.org/10.1371/journal.pone.0242905.
19. Sayedalamin Z, Alshuaibi A, Almutairi O, Baghaffar M, Jameel T, Baig M. Utilization of smart phones related medical applications among medical

students at King Abdulaziz University, Jeddah: A cross-sectional study. *J Infect Public Health*. 2016;9(6):691-97 https://doi.org/10.1016/j.jiph.2016.08.006.
20. Yousef M, Omer A, Alamoudi RA, Alharbi M, Aljehani B, Felemban Z, et al. From awareness to integration: Mobile applications as tools in radiology education. *Journal of Radiation Research and Applied Sciences*. 2025;18(2):101353 https://doi.org/https://doi.org/10.1016/j.jrras.2025.101353.
21. Raosoft I. Sample size calculator by Raosoft 2020 [11 June 2024]. Available from: http://www.raosoft.com/samplesize.html.
22. Fernández-Lao C, Cantarero-Villanueva I, Galiano-Castillo N, Caro-Morán E, Díaz-Rodríguez L, Arroyo-Morales M. The effectiveness of a mobile application for the development of palpation and ultrasound imaging skills to supplement the traditional learning of physiotherapy students. *BMC Med Educ*. 2016;16(1):274 https://doi.org/10.1186/s12909-016-0775-1.
23. Alsharif W, Davis M, Rainford L, Cradock A, McGee A. Validation of the educational effectiveness of a mobile learning app to improve knowledge about MR image quality optimisation and artefact reduction. *Insights into Imaging*. 2018;9(5):721-30 https://doi.org/10.1007/s13244-018-0635-0.
24. Ahmadu OT, Umar SS, Jimeta DJ, Theyra HE. Assessment of Knowledge, Attitude and Utilization of Nuclear Medicine Imaging among Clinical and Radiation Oncologists in Nigeria. *Journal of Medical and Basic Scientific Research*. 2023;4(1-2):43-50.
25. Lampignano J, Kendrick LE. *Bontrager's Handbook of Radiographic Positioning and Techniques-E-Book*. 10th edition ed: Mosby; 2021.
26. Badiauzzaman ISM. Assessment of the usage of mobile applications (APPS) in medical imaging among medical imaging students. *INTERNATIONAL JOURNAL OF ALLIED HEALTH SCIENCES*. 2018;2(2):347-56 https://doi.org/10.31436/ijahs.v2i2.171.
27. Lewis TL, Aungst TD, Hutchinson C. Radiology education, mobile technology and medical apps. *BMJ Simul Technol Enhanc Learn*. 2015;1(2):45-48 https://doi.org/10.1136/bmjstel-2014-000009.
28. Greene LR, Spuur KM. Undergraduate use of medical radiation science mobile applications. *Radiography (Lond)*. 2018;24(4):352-59 https://doi.org/10.1016/j.radi.2018.04.012.
29. Franko OI, Tirrell TF. Smartphone app use among medical providers in ACGME training programs. *J Med Syst*. 2012;36(5):3135-9 https://doi.org/10.1007/s10916-011-9798-7.
30. Singer LM, Alexander PA. Reading Across Mediums: Effects of Reading Digital and Print Texts on Comprehension and Calibration. *The journal of experimental education*. 2017;85(1):155-72 https://doi.org/10.1080/00220973.2016.1143794.
31. Aungst T. Survey results show how medical student use of medical apps differs from resident physicians: iMedicalApps; 2013 [1 June 2024]. Available from: https://www.imedicalapps.com/2013/04/survey-medical-student-medical-app-resident-physician/.
32. Tran K, Morra D, Lo V, Quan SD, Abrams H, Wu RC. Medical students and personal smartphones in the clinical environment: the impact on confidentiality of personal health information and professionalism. *J Med Internet Res*. 2014;16(5):e132 https://doi.org/10.2196/jmir.3138.
33. Quant C, Altieri L, Torres J, Craft N. The Self-Perception and Usage of Medical Apps amongst Medical Students in the United States: A Cross-Sectional Survey. *Int J Telemed Appl*. 2016;2016:3929741 https://doi.org/10.1155/2016/3929741.
34. Nilsson PM, Todsen T, Subhi Y, Graumann O, Nolsøe CP, Tolsgaard MG. Cost-Effectiveness of Mobile App-Guided Training in Extended Focused Assessment with Sonography for Trauma (eFAST): A Randomized Trial. *Ultraschall Med*. 2017;38(6):642-47 https://doi.org/10.1055/s-0043-119354.