The impact of operator training on the accuracy of DXA lumbar spine analysis

McDermott, E.[a], .[c]Dutruit, Y.[c], Jeanneret-Grosjean C, Koen, K.[b] , McPhilomy, C.[a], Snelders, F.[d], Stensrud, K.[d], Tcacenco, A.[a], Aandahl, I-J.[d]

a Radiography and Diagnostic Imaging, School of Medicine, University College Dublin, Dublin, Ireland

b Department of Medical Imaging and Radiation Therapy, Hanze University of Applied Sciences, Groningen, The Netherlands

c Haute École de Santé Vaud - filière TRM, University of Applied Sciences and Arts Western Switzerland, Lausanne, Switzerland

d Department of Life Sciences and Health, Oslo Metropolitan University, Oslo, Norway

Keywords:

DXA, osteoporosis, training, x-ray.

ABSTRACT

Introduction

This study involving Dual-energy X-ray Absorptiometry (DXA) spine images investigated the effectiveness of an additional training session compared to basic instruction provided by the scanner manufacturer (by video) on student radiographers' ability to make appropriate DXA analysis decisions. Lack of operator training can potentially lead to technical errors and inaccurate patient diagnosis which may be detrimental to their bone health and put them at risk of a fragility fracture in the future.

Methods

Radiography students (n=24) attending the OPTIMAX research summer school in University College Dublin (UCD) participated. The students first watched a video that was provided with the DXA scanner software. This video explained the basic process of analysing a DXA spine image. Participant knowledge of understanding how to analyse a DXA spine image was then assessed by questionnaire. Immediately after the completion of the first questionnaire , an expert DXA radiographer (16 years experience) provided a training session on DXA lumbar spine analysis, giving a more in-depth, comprehensive and step-by step tutorial on how best to analyse DXA spine images and common pit-falls to be aware of. Lecture notes and a set of DXA guidelines (based on international best practice and on which the lesson was designed) were distributed during the training session. The participants repeated the questionnaire, with access to the tutorial notes and guidelines.

Results

The results of the questionnaire responses pre- and post-training were calculated and demonstrated an improvement in the questionnaire scores post additional training. Data normality was checked by Shapiro-Wilks test and was shown to be parametric. The mean questionnaire score of the post-training group increased by 13.7%, and was shown to be statistically significant with a p value of. 0.002.

Conclusion

The additional DXA training provided positively affected the student radiographers' understanding on how to analyse DXA images.

Introduction

Osteoporosis is a bone disease that occurs when the body loses too much bone, makes too little bone, or a combination of both processes occurring simultaneously. As a result, bones become weak, and are susceptible to fracturing as a result of minor injuries [1]. Due to bone loss caused by osteoporosis and osteopenia, peri- and postmenopausal women above the age of 50 are more likely to fracture bones than premenopausal women [2]. Dual-energy X-ray absorptiometry (DXA) is the 'gold standard' for measuring bone mineral density (BMD), diagnosing osteoporosis, and monitoring changes in BMD over time [1]. The BMD calculated from the DXA scan is converted to a T- and a Z-score (based on World Health Organisation guidelines) and it is from these scores that a diagnosis can be made, and treatment started, if necessary. Therefore, it is essential that these BMD scores are accurate, reliable and reproducible.

Various studies have reported that, for DXA images to be analyzed correctly, the operator should be competent [3,4]. DXA operators are not required to have a formal background education in any healthcare profession, such as nursing or physiotherapy. In some countries (e.g. Ireland), operators are only required to complete a radiation protection course in order to operate a DXA scanner – no formal training in any patient positioning or scanning and analysis techniques is required [5]. Operators are then legally allowed to scan patients using DXA [6].

Due to operator variability and various technical errors, the analysis of DXA exams can be inaccurate [4]. Some of the inaccuracies may be due to precision errors of the machine, but also due to incorrect positioning of the patient, inaccuracy of image analysis during the post-processing stage and variability in the skills of the operators [3]. The aim of this study was to investigate whether training specifically in the area of DXA spine image analysis would improve the operator's ability to analyze the images.

Methods and Materials

A test-retest quantitative method was carried out in this study. The sample population consisted of 24 student radiographers attending the OPTIMAX research summer school in UCD. The students were from seven different countries: Ireland, The Netherlands, Switzerland, Norway, South Africa, Canada and Brazil. They were at various stages of their studies, some in 3 and some in 4-year programmes, with various amounts of time spent on clinical placement. Participants had varying levels of knowledge of DXA scanning ranging from no knowledge of DXA at all to having a basic understanding of what DXA was. It was decided not to include OPTIMAX tutors in the study, due to the possibility of their having experience working in DXA introducing a bias.

Due to the limited numbers of participants available, it was decided not to have a control group and to use all available participants for the study to increase the validity of the results. Participants signed a consent form, their participation was voluntary, and they were free to withdraw from the study at any time. All the images used in the study were anonymised to avoid any possible identification. Ethical exemption was granted by the UCD Research Ethical Committee for the study .

The DXA training and the time intervals of when the data was collected is presented in Table 1.

In step one of the study, all the participants simultaneously watched a 4-minute video produced by the manufacturer of the DXA scanner. This video is provided as a training aid and shows the step by step process of how to analyse a DXA spine image. It did not, however, give any theoretical background on the subject, or discuss the analysis in the context of providing best practice guidelines on the analysis of DXA spine images. This provided the participants with a very basic level of understanding of DXA spine analysis. It was chosen to give the participants an introduction to DXA spine analysis as it mimics what is available to DXA operators in a clinical setting, where no formal training in DXA scanning is offered or available.

Immediately after watching the video, each participant had 25 minutes to complete a questionnaire (step 2, 'Questionnaire 1') with 20 questions. This was in order to establish their baseline understanding of how to analyse a DXA spine images following the training video provided by the manufacturer.

Directly after the questionnaires were completed and returned, the participants were given a training session by an experienced DXA radiographer (step 3). DXA analysis software was used in the training session to demonstrate not only the basics of how to analyse DXA spine images, but also to show examples of the nuances of DXA spine analysis, and the limitations of the software. During this training session, participants also received a handout which outlined the DXA best practice guidelines as produced by the International Society for Clinical Densitometry (ISCD)[7] as well as a copy of the lecture notes. The level of training provided aligned to that currently given within Irish clinical centres as part of "in house" DXA training (verified by personal contact with university teaching centres affiliated with Radiography degree participation).

In step 4 and the final part of the study, the participants completed the initial questionnaire a second time, renamed Questionnaire 2. Participants were permitted to refer to the protocols and notes provided on DXA while answering the questions in this stage of the study.

Questionnaire Design and Image Selection

An online questionnaire website called Socrative [8] was used to create and administer the questionnaire which consisted of 20 multiple choice questions (MCQs) each with a choice of answers, with only one correct choice. In addition, demographic information such as gender, country of participant study, years of training in radiography, and how much time they had spent in clinical placement were asked.

The remainder of the questions related to images which represented different scenarios which commonly presented during the analysis stages of DXA. Images from the internet [9] were used as well as images from the GE Lunar Prodigy iDXA with software version 8.8 [10]. The images were selected to represent typical DXA spine images which operators routinely analyse, including images which tested the operators' decisions as to whether or not to include a vertebra in the DXA analysis. If the vertebrae are not suitable to be included in the analysis, then leaving the vertebrae in would lead to an erroneous result. It is in these situations that the correct training and expertise that the operator has, directly affects the overall results of a DXA scan.

Questions answered by the participants focused on four main aspects of DXA spine analysis, namely in relation to:

- The repositioning of inter-vertebral lines;
- The inclusion or exclusion of vertebra/e in the overall analysis;
- The acceptance of the Region of Interest;
- The requirement to potentially repeat the DXA scan.

Table 1. Outline of training and date collection

Step	Action
Step 1	Participants watch the manufacturers training video
Step 2	The DXA questionnaire administered (Questionnaire 1)
Step 3	Participant underwent a training session (30 min session)
Step 4	The DXA questionnaire re-administered

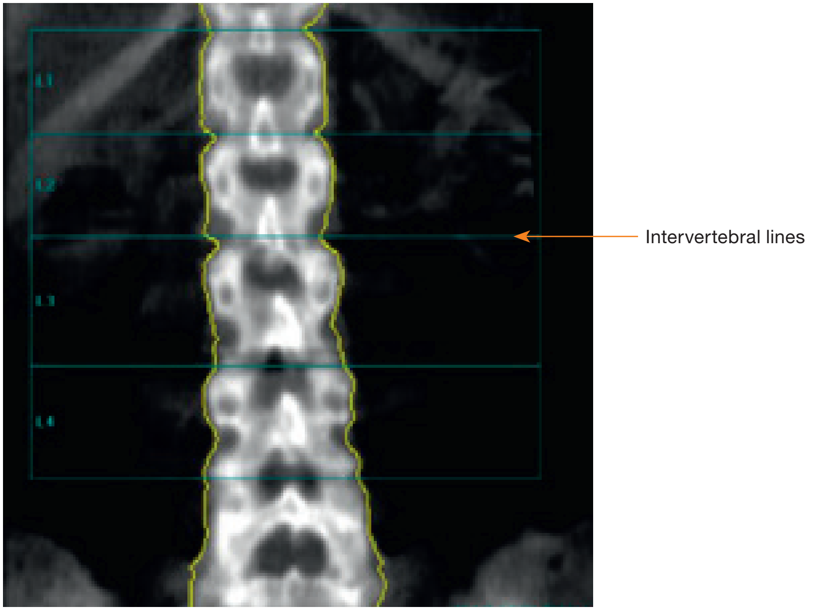

Figure 1. Example of a DXA image (GE Lunar Prodigy iDXA with software version 8.8 [9])

Figure 1 shows a DXA spine image and the arrow points to the intervertebral lines, which may be moved, or angled, as needed.

All questions asked in the questionnaire were based on the difficult aspects and most common mistakes made in DXA analysis [11]. During the image analysis sessions, the images were displayed on the participants laptops via BlackBoard, (the online learning environment used in UCD) and they were also projected onto a large screen within the participant viewing room. Ambient lighting was kept low to mimic clinical reporting rooms and this remained constant throughout the study during image review periods.

A pilot study was performed which involved three participants to test the study instructions. Some wording was adapted to accommodate the different levels of English of the participants to minimise the risk of misunderstanding, however the core questions remained unchanged.

Statistical Analysis

Statistical analysis was performed using SPSS Software Version 24.00[12]. A normality test was performed. The significance value (p=0.573), on the Shapiro-Wilk scale, showed that the data was normally distributed and therefore a paired two-tailed t-test could be performed with accuracy. An ANOVA test which is an analysis of variance, assessed the potential differences between the scale-level variables and the nominal-level variables, such as gender and country. The reference cut-off value of significance used was ($p \leq 0.05$). The paired two-tailed t-test was chosen to determine if there was a statistically significant difference between the two questionnaires before and after the additional DXA training once it was established that the data was normally distributed.

Results

The sample population consisted of 24 radiography students attending a three-week research summer school in UCD. The sample comprised of 37.5% male and 62.5% female students. They had various years of studying completed and studied in five different countries, as presented in Table2.

The results showed an increase of 13.9% in the mean score of correct responses between the post training group (61.9%) vs. the pre-training group (48%), with a p-value of 0.002. As this p-value is <0.05, this improvement has been shown to be statistically significant. A paired T-test was then carried out on the

Table 2. Participant demographics

	Years of Study Completed						
	1		2		3		4
No. of Students (n=24)	5 (20%)		14 (58%)		3 (12%)		2 (8.3%)
	Country of Study						
	Ireland	Nether-lands	Norway	Switzer-land	Canada	Brazil	South Africa
	5 (20%)	5 (20%)	5 (20%	5 (20%)	1 (4%)	1 (4%)	2 (8.3%)

Table 4. The mean difference in correct responses post additional DXA training.

	Mean	Std. Dev.	Std. Error Mean	Sig. (2-tailed)
Intervertebral Lines	0.333	2.082	1.202	0.808
Exclude Vertebrae	3.800	2.864	1.281	0.041
Regions of Interest	8.667	4.726	2.728	0.086
Repeat Scan	0.500	1.915	0.957	0.638

participant responses when categorised into the four groups of typical types of analysis carried out on DXA spine images, outlined in the methods. The results are presented in Table 4.

The correct responses pre- and post-training session were identified and an increase of 15.84% in the number of correct responses in the category of ‘’excluding vertebrae’’ was found to be statistically significant with a p-value of p=0.041. However, in relation to the other three categories labelled; ‘Intervertebral lines’, ‘regions of interest’, and ‘repeat scan’ none were deemed, statistically significant, with p-values of 0.808, .086 and 0.638 respectively.

An ANOVA test was applied to elements of the demographic data and is the statistical technique that was employed to assesses potential differences in scale-level dependent (e.g. exam scores) variables by a nominal-level variable (e.g. years of study) having 2 or more categories. Gender, clinical experience, year of study or country of study were investigated, however they were found not to statistically significantly influence the increase in correct answers findings were as follows: participants clinical experience (p=0.110), gender (p=0.635), years of radiography study (p=0.927) and their country of origin (p=0.194). These categories, therefore cannot be assumed to have influenced the participants’ ability to answer the questions correctly for either questionnaire one or questionnaire two.

Discussion

The aim of the study was to determine whether training in DXA spine analysis would impact the operator’s ability to analyse DXA spine scan more accurately. The accuracy of the participants in analysing DXA scans pre- and post-training with an experienced DXA radiographer was tested. The correct questionnaire responses pre- and post-training were analysed and compared, and it was found that the total of correct answers in the post-training questionnaire had increased by 13.7%. This positive change in knowledge, with respondents answering more questions correctly post training, was shown to be statistically significant with a p-value 0.002, suggesting that the training had a positive impact on the participants ability to make better decisions on how to correctly analyse DXA spine images. It also suggests that the ‘training’ video supplied by the DXA manufacturer independantly, may not give operators comprehensive training in the analysis of DXA spine images. The study has demonstrated that the participants responded well to the training provided and they were able to apply their new knowlege and understanding to the analysis questions post training.

The training provided by the expert DXA radiographer (16 years DXA training) was based on the key-points of DXA lumbar spine analysis as well as the most common mistakes made by DXA operators [1]. Emphasis was placed on excluding unsuitable vertebrae, the placement of vertebral body lines and border and the importance of understanding when this was necessary. This aspect of the analysis was not discussed in detail in the training video provided by the DXA manufacturer. The study incorporated four key aspects of DXA scan analysis labelled ‘intervertebral lines’, ‘excluding vertebrae’, ‘region of interest’ and ‘repeat the exam or not’. The category of ‘excluding vertebrae’ resulted in substantial differences in correct responses post-training compared to the pre-training responses (p=0.041). Whilst the remaining three categories were not statistically significant. It is difficult to predict why one area of analysis in particular appeared to illicit more correct responses than the others. It could possibly be due to a language barrier which may have caused a lack of comprehension in some aspects of the training. The participants were from various countries and English was not the first language of many. Questions and answers were written in basic English to accommodate most levels of understanding and was tested by means of a pilot test and deemed appropriate.

The information in the questionnaire and the handout, however, may still have been interpreted incorrectly putting the non-native English speakers at a disadvantage, thus affecting the overall findings. The level and understanding of English of the participants was not measured prior to the study because of the limited time-frame in which the study had to be completed. Some questions were found to have a decrease in the amount of correct responses after the training, but it was not possible to determine if this was due to comprehension / level of English or reading ability, as no baseline had been established. It would have been interesting to see if a language barrier impeded the comprehension of the training, and thus the ability to understand the subtleties in DXA image analyses, thereby affecting the overall significance of the results.

The participants from the Netherlands showed a relatively large difference in the correct responses pre- and post-training in compared to participants from other countries. Whilst overall study findings did not identify the participants country of origin to be not significantly significant, the observation of improvement in this particular group may be due to a better level of English in these students or possibly the training method carried out in this study being a similar learning style that these participants are used to.

The participants in this study came from different educational backgrounds and therefore may have different learning styles and study preferences, which may have affected the results. This was not taken into consideration in this study. Passive learning, where the student does not interact with the content, but is merely present and lectured to, as was the method of 'training' in this study, is only one way in which students learn. Those learning in this way have been shown to only retain 10%-50% of the content [13]. However, active learning, which involves listening to a lecture and then interacting with the content for a short time directly after in smaller groups, has been shown to increase retention up to 90% [14]. This could be a possible limitation and reason to conduct further research to acknowledge different learning styles and recollection of information given which could include not only using a more active learning style during the training phase, but also to include a method in the data collection which captures the learning style the students participating in the study are used to. This may potentially assist in understanding why participants may or may not take in the information during the training and learning phase. The impact of training in this study is focused upon student radiographers who are novices in DXA, the inclusion of qualified radiographers may render different findings and requires investigation.

Factors such as number of years of radiography study or time spent on clinical placement were examined. It could have been assumed that these factors would have contributed to participant knowledge, as they are directly related to knowledge of anatomy and radiographic practice, though not specifically DXA experience. However, this was not shown to be the case when tested statistically ($p>0.05$), so therefore did not affect the outcome of the results. Other incidental factors, such as gender and country of origin were then considered and again were not shown to be significant ($p>0.05$),

Based on the study findings, training improved the ability of participants in making correct decisions regarding the analysis of DXA lumbar spine images. There is some evidence to suggest that placing emphasis on certain aspects of training significantly improves operator competency in those areas, as evidenced by the increase in the correct answers in the area of 'excluding vertebra'. Further research is recommended, using a larger cohort and including a control group without any training, with participants with the same level of English, which may reduce the adverse effect a language barrier may have on the responses. A more detailed questionnaire / method of collecting data may allow a better understanding of other factors that may have significant impact on an operator's ability to accurately analyse DXA lumbar spine scans, thereby producing a more reliable result for patients.

Conclusion

The purpose of this study was to investigate if focused training for novices undertaking analysis of DXA lumbar spine images improved DXA operators' accuracy. The results identified that when training was provided by a radiographer experienced in DXA this positively impacted the participants' ability to make appropriate decisions, and correctly analyse DXA spine images.

The results also showed that clinical experience (as students) and number of years of completed study did not impact the study findings. The results demonstrated that the improvement post additional training was independent of country, gender, and years studied. This further demonstrates that correct training reduces the risk of errors in DXA analysis for a range of participant demographics, as no other factors were shown to be statistically significant.

References

1. Learn What Osteoporosis Is and What It's Caused by [Internet]. National Osteoporosis Foundation. [cited 2018 Aug 3]. Available from: https://www.nof.org/patients/what-is-osteoporosis/
2. Morgan SL, Prater GL. Quality in dual-energy X-ray absorptiometry scans. Bone. 2017 Nov 1;104:13–28.
3. Roux C, Briot K. Current role for bone absorptiometry. Joint Bone Spine. 2017 Jan 1;84(1):35–7.
4. Carey JJ, Delaney MF. Utility of DXA for monitoring, technical aspects of DXA BMD measurement and precision testing. Bone. 2017 Nov 1;104:44–53.
5. National questionnaire of Dual Energy X-ray Absorptiometry Services in Ireland [Internet]. Hse.ie. 2014 [cited 2018 Jul 26]. Available from: https://www.hse.ie/eng/about/who/qualityandpatientsafety/safepatientcare/medexpradiatonunit/national%20questionnaire%20of%20dual%20energy%20x-ray%20absorptiometry%20services%20in%20ireland%202014.pdf
6. Book (eISB) electronic IS. electronic Irish Statute Book (eISB) [Internet]. [cited 2018 Aug 3]. Available from: http://www.irishstatutebook.ie/eli/2007/si/303/made/en/print
7. ISCD Certification in Bone Densitometry [Internet]. [cited 2018 Aug 2]. Available from: https://www.iscd.org/certification/
8. Socrative [Internet]. [cited 2018 Aug 2]. Available from: https://www.socrative.com/
9. Google Images [Internet]. [cited 2018 Aug 2]. Available from: https://images.google.com/?hl=fr
10. GE Lunar Prodigy Primo Bone Densitometer [Internet]. Complete Medical Services. [cited 2018 Aug 3]. Available from: https://completemedicalservices.com/imaging-equipment/ge-lunar-prodigy-primo-bone-densitometer/
11. Lewiecki EM, Lane NE. Common mistakes in the clinical use of bone mineral density testing. Nat Clin Pract Rheumatol. 2008 Dec 4;(12):667–74.
12. IBM SPSS Software | IBM Analytics [Internet]. [cited 2018 Aug 3]. Available from: https://www.ibm.com/analytics/spss-statistics-software
13. Davies N. Student life - It pays to maximise your learning power. Nursing Standard. 2015 Sept 02 ; 30(1): 66-66.
14. Anderson, I. (2016). Identifying different learning styles to enhance the learning experience. *Royal College of Nursing Publishing Company.* 31(7), 53-63. doi:10.7748/ns.2016.e10407