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Dual Energy X-ray Absorptiometry: Radiographer'S Role in Assessing Fracture Risk Assessment Tool (FRAX) Questionnaire Variables

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Abstract

Background: The FRAX® algorithm is a tool used to calculate the 10-year probability of fracture in patients with osteoporosis and is based the assessment of several risk factors. We assessed the performance and accuracy of the completion of the FRAX® anamnestic questionnaire by the radiographer without impact on the clinical workflow.

Methodology: We evaluated the accuracy of fracture risk calculation by the radiographer using the FRAX® algorithm before and after specific training. A total of 100 women were enrolled in the study. The radiographer preliminarily administered the FRAX® questionnaire to all subjects before the execution of the DXA examination. After the end of the examination, a radiologist administered the questionnaire to the patient. Women were divided into two groups: group A (pre-training) and group B (post-training). The radiographer in group A completed the FRAX® questionnaire for the patients before training. For group B, the same radiographer completed the FRAX® questionnaire after training. The results of the FRAX® questionnaire completed by radiographer were compared with that completed by the referring physician.

Results: Before training, radiographer's accuracy ranged from 92% (question 7, alcohol consumption) to 36% (question 6, secondary osteoporosis). After training, accuracy values improved substantially, ranging from 100% to 92%. Analysis of the absolute values of FRAX® showed that in the pre-training group data tended to be overestimated by the radiographer, with both major and fractures probabilities being significantly higher when assessed by the radiographer (12% and 5.8%, respectively). After the training, there was a marked decrease in the variation between the FRAX® data calculated by the radiographer and the radiologist.

Conclusions: The accuracy of fracture risk calculation by the radiographer using the FRAX® algorithm is significantly improved after a specific training period. This study demonstrates the importance of dedicated training radiographers on the FRAX® algorithm.

Keywords: FRAX®; Fracture risk; Radiographer; Training; Accuracy.

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Introduction

Osteoporosis is a prevalent metabolic bone disease characterized by reduced bone mass and microarchitectural deterioration, resulting in increased bone fragility and fracture risk.[1] Fractures associated with osteoporosis lead to significant morbidity, mortality, and healthcare costs.[2,3] There are two main forms of osteoporosis: primary and secondary. Primary osteoporosis, including postmenopausal and senile osteoporosis, is the most prevalent type, while secondary osteoporosis can be caused by various diseases, pharmacological agents, or other conditions.

The incidence of osteoporosis rises progressively with age, and it is expected that the incidence of osteoporosis will continue to increase proportionally.[4] Bone mass plays a critical role in determining bone strength and resistance to mechanical stress,[5] and low bone mass is closely associated with an elevated risk of fractures. Early identification of individuals with reduced bone mass is crucial for timely intervention. Several densitometric techniques have been developed since the 1960s to assess bone mineral density (BMD), with dual-energy X-ray absorptiometry (DXA) being the current reference standard technique for the diagnosis of osteoporosis according to the World Health Organization criteria.[6–8] DXA provides quantitative data and requires precise execution and analysis, making the role of radiographers vital in obtaining high-quality DXA exams. Radiographers, along with radiologists, ensure the accurate execution of DXA examinations, as errors during the procedure can affect the quality and accuracy of the results.

To assess the risk of major fragility fractures beyond BMD, algorithms such as FRAX® have been developed. FRAX ® online tool (available at http://www.shef.ac.uk/FRAX) is widely available and clinically validated,[9–11] and one of the screening tools used for predicting risk of fracture.[12] FRAX® combines the BMD of the femoral neck with constitutional and anamnestic risk factors such as age, sex, body mass index (BMI), presence of previous fragility fractures, history of parents with femur fractures, smoking and alcohol habits, long-term use of glucocorticoid drugs, and a diagnosis of rheumatoid arthritis or other diseases associated with secondary osteoporosis.[13] The output obtained from the algorithm is a 10-year probability of a hip fracture and the 10-year probability of a major osteoporotic fracture (hip, vertebral, humerus or wrist).

Radiographers play a pivotal role to obtain high-quality DXA exams, as they usually are those in charge for DXA acquisition and analysis. Many errors can occur both during execution and analysis - the so-called 'pitfalls' – possibly affecting the quality and accuracy of DXA examination.[14]

Considering that the latest generation of densitometers require the inclusion of the FRAX® variables before performing the DXA examination, the subsequent integration with BMD data can automatically provide the fracture risk estimation attached to the DXA report. To this purpose, the FRAX® anamnestic questionnaire can be administered by the radiographer to the patient before DXA execution. The aim of our study was to assess the performance and accuracy of the FRAX® anamnestic questionnaire by the radiographer without considerable impact on the clinical workflow. The study seeks to shed light on the potential effectiveness of training programs in improving fracture risk calculation and determining whether radiographers can accurately collect patient medical/clinical history for FRAX® assessments, comparing it with the results obtained from the radiologist (referring Physician) as a reference standard.

Materials and methods

Ethical approval was not sought for the present study due to the observational nature of the study and taking into consideration that all procedures fall within the clinical standard and internal policy. Informed consent was not required due to the observational nature of the research.

Radiographer's training

The radiographer underwent a one-hour training starting from a brief explanation of the importance of early detection and fracture risk assessment in osteoporosis. After providing an overview of the FRAX® and explaining the purpose of this tool in assessing fracture risk, the specific components of FRAX® calculation: (age, gender, BMI, previous fractures, parental hip fractures, glucocorticoid use, etc.). Several simulations were done walking through each question on the FRAX questionnaire, practically demonstrating how to input questionnaire responses into the FRAX tool. Any doubts or difficulties of interpretation were promptly clarified, as often as necessary.

Study population and FRAX® questionnaire

We prospectively analyzed patients referred to our Institution (IRCCS Istituto Ortopedico Galeazzi, Milan, Italy) for clinical routine DXA examination. None of the patients underwent DXA for the sole purpose of the study. Patient FRAX® questionnaire assessment started in June 2021.

We included post-menopausal women aged older than 40 years. Reasons for exclusion include only those related to the inability to perform DXA. We decided to include only females as they represent the majority of subjects referred for clinical routine DXA examination in our Institution, with very few males attending during the enrollment period.

Before conducting the DXA examination, patients were required to respond to questions from the FRAX®

questionnaire, which assesses both constitutional and anamnestic risk factors (Table 1).

A radiographer with more than 5 years of experience in performing DXA examinations participated in the study and received a specific training on the FRAX® questionnaire administration by a radiologist (CM) with more than ten years of experience in osteoporosis imaging.

According to the training, the study population was divided in two equal groups:

- Group A (pre-training): individuals subjected to the FRAX® questionnaire by the radiographer before the training.
- Group B (post-training): individuals subjected to the FRAX® questionnaire by the radiographer after the training.

The radiographer preliminarily administered the FRAX® questionnaire to all subjects before the execution of the DXA examination. After the end of the examination, the physician (a radiologist) administered the questionnaire to the patient. The results of the FRAX® questionnaire performed by the radiologist were considered as the reference standard. Both the radiographer and the radiologist were blinded to each other's results.

DXA acquisition

BMD assessment was conducted using a Hologic Discovery W densitometer DXA, at both the lumbar spine and the proximal femur levels. For lumbar spine BMD measurements, analysis was performed on the first four vertebrae (L1-L4) following the guidelines of the International Society for Clinical Densitometry.[15] Vertebrae with severe degenerative changes or fractures were excluded from the analysis if the T-score difference with the adjacent vertebra adjacent vertebra was > 1.0. All lumbar scans were performed using the support cushion positioned under the calves, which allows to position the hips in flexion at 90° to the spine, to decrease the lordosis of the spine (at 90°). The femoral scan was performed with the patient in supine decubitus position. The provided hip positioning device was placed under the patient's legs and centered along the mid-body axis to ensure accurate alignment. This device supports the foot firmly in the correct position and ensures that the femur

Table 1
Detailed item list of FRAX® questionnaire.

Age	The model accepts ages between 40 and 90. If lower or higher ages are included, the program will calculate the probabilities at 40 and 90 years respectively
Gender	Male or female, as appropriate.
Weight	In kg
Height	In cm
Previous fracture	A previous femoral fracture or a vertebral fragility fracture (i.e. occurred spontaneously in adulthood or following a minor trauma). A fracture detected only by radiographic observation (morphometric vertebral fracture) is also considered positive for previous fracture. A previous fracture denotes more accurately a previous fracture in adult life occurring spontaneously, or a fracture arising from trauma which, in a healthy individual, would not have resulted in a fracture. Yes or no.
Parents with femoral fracture history	This enquires for a history of hip fracture in the patient's mother or father. Yes or no.
Current smoking	Enter yes or no depending on whether the patient currently smokes tobacco.
Glucocorticoids	Yes if the patient is currently exposed to oral glucocorticoids or has been exposed to oral glucocorticoids for more than 3 months at a dose of prednisolone of 5mg daily or more (or equivalent doses of other glucocorticoids). Otherwise no.
Rheumatoid arthritis	Enter yes where the patient has a confirmed diagnosis of rheumatoid arthritis. Otherwise no.
Secondary osteoporosis	Enter yes if the patient has a disorder strongly associated with osteoporosis. These include type I (insulin dependent) diabetes, osteogenesis imperfecta in adults, untreated long-standing hyperthyroidism, hypogonadism or premature menopause (<45 years), chronic malnutrition, or malabsorption and chronic liver disease. Otherwise no.
Alcohol consumption	Enter yes if the patient takes 3 or more units of alcohol daily. A unit of alcohol varies slightly in different countries from 8-10g of alcohol. This is equivalent to a standard glass of beer (285ml), a single measure of spirits (30ml), a medium-sized glass of wine (120ml), or 1 measure of an aperitif (60ml). Otherwise no.

remains in the position required to keep the hip in axis. The entire lower limb is rotated 25° inwards, and the foot is then placed on the positioning device.

Osteoporosis and "reduced bone mass" diagnosis

The diagnosis of osteoporosis and *reduced bone mass* were made according to the lowest T-score between the lumbar spine and femoral neck, in agreement with the criteria of the World Health Organization (WHO). These are based on reference curves of BMD and are defined as follows[16]: normal (T-score > -1), *reduced bone mass* (T-score between -1 and -2.5) and osteoporosis (T-score < -2.5).

Statistical analysis

The normal distribution of the continuous variables was assessed by means of the Kolmogorov-Smirnov test or the Shapiro-Wilk test, depending on the sample size. For normally distributed values, the data were presented as mean ± standard deviation (SD), and the variables were compared using the dependent sample t-test. A p-value less than 0.05 was considered statistically significant[17]. Statistical analysis was performed using SPSSv25 (SPSS Inc, Chicago, IL, USA).

Results

Study population

A total of 100 women were enrolled, with a mean age of 67 ± 10 years (mean ± SD).

The women belonging to group A (PRE-TRAINING) showed a mean age of 66 ± 10 years (mean ± SD), while women belonging to group B (POST-TRAINING) presented a mean age of 68 ± 10 years (mean ± SD). All patients were in a spontaneous post-menopausal state and had no significant risk factors for secondary osteoporosis. An overview of the characteristics between the two groups can be seen in Table 2.

The two groups were homogeneous in relation to the variables analyzed. The body mass index (BMI) was similar between group A (BMI = 24.5±1.1) and group B (BMI = 25.9±1.2); this difference was found to be statistically insignificant.

BMD analysis of the lumbar spine, performed on the L1-L4 vertebrae (except for any vertebrae excluded from the analysis due to altered structure) showed no statistically significant differences between the Group A (0.815±0.137) and Group B (0.831±0.141). Similarly, no statistically significant changes between the BMD of the femoral neck of subjects in group A (0.667±0.107) and group B (0.644±0.130) was found.

Based on femoral and lumbar T-score values, the following diagnoses were made among Group A (osteoporosis n=15, *reduced bone mass* n=24, normality n= 11) and among Group B (osteoporosis n=16, *reduced bone mass* n=28, normality n= 6).

Comparison between radiologist and radiographer on FRAX® questionnaire

The 7 items that constitute the anamnestic factors of the FRAX® questionnaire were analyzed.

The analysis of the accuracy of the radiographer in reporting the correct data in the FRAX® compared with the radiologist (reference standard), both before and after the training, is reported in Table 3 and demonstrated an improvement in the accuracy of the radiographer in taking in and filling in the FRAX® algorithm questions before and after the training.

Regarding the results before training, accuracy varied between a maximum of 92% (for question 7 related to alcohol consumption) and a minimum of 36% (for question 6 related to the secondary osteoporosis).

Table 2
Overview of the characteristics between group A (pre-training) and group B (post-training).

	Group A PRE-TRAINING (n=50)	Group B POST-TRAINING (n=50)	p-value
Age (years)	66±10	68±10	0.846
BMI (kg/m^2)	24.5±1.1	25.9±1.2	0.620
Spine BMD	0.815±0.137	0.831±0.141	0.846
Spine T-score	−1.7±1.1	−1.9±1.4	0.630
Femoral neck BMD	0.667±0.107	0.644±0.130	0.816
Femoral neck T-score	−1.8±0.9	−1.7±1.2	0.780
Major FRAX®	7.7 [5.4−11.0] *	7.3 [5.1−10.0] *	0.240
Hip FRAX®	2.4 [1.0−3.7] *	1.5 [0.8−3.0] *	0.364

BMI = Body Mass Index; BMD = Bone Mineral Density.
*= non-normally distributed values, expressed as median with interquartile range [25-75].

Other questions in which the radiographer's accuracy was less than 50% were question 5 regarding whether rheumatoid arthritis was present (accuracy = 42%) and question 4 regarding corticosteroid use (accuracy = 48%).

The questions in which radiographer's performance was best were, in addition to question 7, question 1 (history of previous fracture) and question 2 (history of parent with fractured femur).

After training, accuracy values improved substantially, and no value was less than 50%. In detail, accuracy values after training ranged from a high of 100% (thus similar result to the referring Physician) to a low of 92% (for question 6). A line chart showing the radiographer variations of accuracy between the pre-training and post-training is reported in Fig. 1.

Analysis of the sources of error of individual questions was conducted and showed that the most common errors were variable; in particular: for question 1 (prior fracture) the radiographer often reported non-fragility fractures, such as those that occurred due to effective trauma or fractures at a young age. For question 2 (parent with fractured femur), any kind of fracture was reported instead of femoral fractures. For question 3 (habitual smoker), the radiographer in some cases scored 'yes' for remote exposures, no longer significant according to FRAX®, while he scored 'no' for active smoking considered insignificant ("few cigarettes per day"). For question 4 (corticosteroids), in some instances the answer was 'yes' even if the dosage was below the threshold. For question 5 (rheumatoid arthritis), in many cases degenerative osteoarthritis was considered as rheumatoid arthritis. For question 6 (secondary osteoporosis), sometimes a possible cause of secondary osteoporosis was not reported as such; in other cases, an unrelated condition was wrongly marked as secondary osteoporosis.

For question 7 (alcohol consumption) errors were less frequent: only in few cases 'yes' was scored, even though consumption was below the threshold of 3 units per day.

Analysis of the variation of FRAX® values before and after training

Table 4 shows the analysis in detail of how FRAX® values varied before and after training for both major and femur fractures.

Analysis of the absolute values of FRAX® showed that in the pre-training group data tended to be overestimated by the radiographer: both the probability of major fractures and femur fractures were significantly higher when assessed by the radiographer (12% for major fractures and 5.8% for femur fractures) than by the radiologist (7.7% for major fractures and 2.4% for femur fractures). After the training, there was a marked decrease in the variation between the FRAX® data calculated by the radiographer and those of the radiologist.

In fact, even if values were slightly higher for the radiographer, no statistically significant differences were found between the values calculated by the radiographer (8.1% for major fractures and 1.8% for femur fractures) and those calculated by the Physician (7.3% for major fractures and 1.5% for femur fractures).

Discussion

In this study, we demonstrated how the accuracy of fracture risk calculation by the radiographer, using the FRAX® algorithm, significantly improved after a specific training period. After the training, the accuracy values became comparable with those of the radiologist. Similarly, we observed a significant change in the absolute FRAX® values for calculating the 10-year fracture probability for both major and proximal femur fractures. As a matter of fact, after training, the differences in FRAX® values between the radiographer and the Physician were no longer significant, in contrast to pre-training.

So far, this is the first study to evaluate the performance of the radiographer in performing the FRAX® questionnaire. Other studies have evaluated the role of

Table 3
Comparison of the accuracy of the radiographer in reporting the correct data in FRAX® compared with the physician (reference standard), both before and after training.

		SET BEFORE TRAINING			SET AFTER TRAINING		
	ITEM	Physician	Radiographer	Acc.	Physician	Radiographer	Acc.
1	Previous fracture	50/50	43/50	86.0%	50/50	48/50	96.0%
2	Parental Femoral Fracture	50/50	42/50	84.0%	50/50	50/50	100.0%
3	Habitual smoker	50/50	40/50	80.0%	50/50	47/50	94.0%
4	Corticosteroids use	50/50	24/50	48.0%	50/50	43/50	86.0%
5	Rheumatoid arthritis	50/50	21/50	42.0%	50/50	47/50	94.0%
6	Secondary osteoporosis	50/50	18/50	36.0%	50/50	46/50	92.0%
7	Alcohol consumption	50/50	46/50	92.0%	50/50	50/50	100.0%

Acc. = accuracy

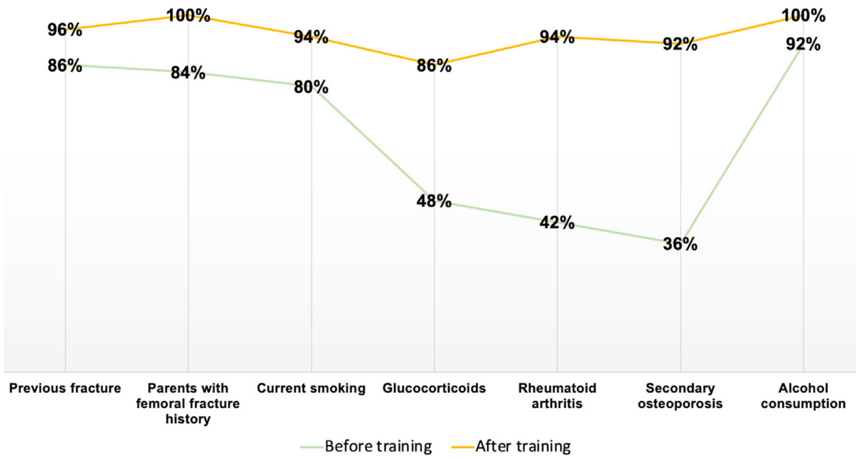

Fig 1. Line chart showing the variations of accuracy for the radiographer between the pre-training and post-training, according to the different FRAX® questions.

the radiographer during DXA surveys in the past. In 2015, Rud et al. evaluated the accuracy of the radiographer in performing vertebral morphometries with DXA technique, so-called vertebral fracture assessment (VFA) performed on lateral DXA scans to identify vertebrae with fractures.[18] The study showed a reasonable degree of confidence on the part of the radiographer in identifying fractures, which reached acceptable accuracy values especially for grade II and III vertebral fractures. The study concluded that the use of the VFA technique by the radiographer at least for preliminary purposes is feasible.

Risk assessment using the FRAX® algorithm, as well as other algorithms, can often be problematic in clinical practice: these algorithms must be based on readily available and usable information. When the variables considered are not so easily accessible, or are too numerous, the risk is that the algorithm will be clinically unimplementable.

On the other hand, FRAX® was often thought to be based on too few factors, which are not properly stratified, and therefore risk stratification by the algorithm may lack accuracy. Based on these considerations, and to overcome some of the limitations of FRAX®, a new algorithm was developed in Italy and called DeFRA.[19] It is a FRAX®-derived tool, based on fracture risk data from the Italian population, which more accurately stratifies some of the variables already present in FRAX®.[20] However, this tool is mostly used by clinicians during visits, as it is more complex.

The advantages of entering the FRAX® into the DXA survey are many. First, the BMD data is automatically integrated by the densitometer into the FRAX®. Second, the patient gets valuable additional information immediately and contextually with the DXA, as it can provide a wake-up call if the risk of fracture is particularly high.[21] Consequently, it is important that the data provided is accurate, because the DXA examination is performed and analyzed by the radiographer, who has a key role in ensuring that the examination is successful.

The results of our study showed a tendency for the radiographer to overestimate fracture risk using FRAX®. This occurred in relation to the lower accuracy in the assessment of risk factors, which are known to be the most controversial questions regarding the FRAX® algorithm.[22] Risk factors such as smoking and corticosteroids have a dose-dependent effect: the higher the exposure to such substances, the greater the risk. This fact is given little consideration in FRAX® and there is often a tendency to make an arbitrary choice of ‘yes’ or ‘no’, even under conditions where it is not easy to make a clear choice. It is possible that the radiographer in these situations is likely to be more led to overestimate the risk factor by

Table 4
Analysis of the change in FRAX® values before and after training for both major fractures (major FRAX®) and femur fractures (hip FRAX®).

	GROUP A (PRE-TRAINING)			GROUP B (POST-TRAINING)		
	Physician	Radiographer	p-value	Physician	Radiographer	p-value
Major FRAX®	7.7 [5.4–11.0]	12.0 [7.8–18.0]	0.039*	7.3 [5.1–10.0]	8.1 [5.5–11.3]	0.253
Hip FRAX®	2.4 [1.0–3.7]	5.8 [2.0–7.0]	0.046*	1.5 [0.8–3.0]	1.8 [1.0–3.5]	0.364

Data are expressed as median with interquartile range [25-75].

indicating 'yes', even in cases where this risk is not concrete. The results of our study well fit into this scenario, and further validate the role of the radiographer in performing the DXA survey.

Among the different FRAX® questions, the number six related to "secondary osteoporosis" assessment was that with the lowest pre-training accuracy. Our explanation is that question six is among the most complex, as it considers anamnestic factors that are more difficult to investigate, and often require more experience in the clinical setting of osteoporosis. Specific attention should be paid to this question during radiographer training for FRAX® questionnaire.

The main limitation of this study is the questionnaire filled by a single radiographer, which may impact on the representativeness of the sample, as results may not be representative of radiographers in other clinical settings or with different levels of experience. The reason is that during the enrollment period, we only had one dedicated radiographer performing all DXA scans. While this is surely a limitation about the estimation of inter-operator reproducibility, the fact that we conducted the study with a dedicated radiographer reassures us about its high level of experience.

In conclusion, this study demonstrated how the accuracy of fracture risk calculation by the radiographer, using the FRAX® algorithm, is significantly improved after a specific training period. This study demonstrates how the radiographer can be supportive of the DXA reporting activity of the physician, even in the fracture risk assessment scenario. It remains crucial to monitor the radiographer's answers in the FRAX or other algorithms, and assure continuous technical preparation. The constant cooperation between radiographer and radiologist is essential to ensure the most accurate DXA examinations aimed at a better patient care and improving fracture risk assessment.

Declaration of Competing Interest

None.

Acknowledgments

Authors' roles: CMes and MZ contributed to study design, data acquisition, analysis and interpretation, manuscript drafting; CMen, PG, and SF contributed to data acquisition and manuscript revising; DA revised the manuscript and approved its final version.

CM is responsible for the integrity of the data analysis.

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