**Digital Health Interventions for Osteoporosis and Post-Fragility Fracture Care**

*Amit Gupta\* MBBS BMedSci, Christina Maslen\* BPharm MSc PhD, Madhavi Vindlacheruvu MA MB BCHir, Richard L. Abel PhD, Pinaki Bhattacharya MS (Eng) PhD, Paul A Bromiley MA MSc PhD, Emma M. Clark MSc MBBS PhD, Juliet. E. Compston MD, Nicola Crabtree PhD, Jennifer S Gregory BSc PhD, Eleni P. Kariki MSc PhD, Nicholas C Harvey MA MB BChir PhD, Eugene McCloskey MD FRCPI, Kate A Ward BSc PhD, Kenneth E.S. Poole BM PhD*

On behalf of the Technology Working Group of the Royal Osteoporosis Society Osteoporosis and Bone Research Academy (<https://theros.org.uk/>)

*\*Joint first authors*

**Acknowledgements**

This Rapid Evidence Review was commissioned by the Technology Working Group of the Royal Osteoporosis Society **Osteoporosis and Bone Research Academy**, to inform the Society’s 2020 Research Road Map and Cure Strategy (https://theros.org.uk/osteoporosis-research/research-roadmap/). CM (Health Evidence Matters Ltd) wrote the full review, which was summarised for scientific publication by AG and KESP. The authors are grateful to Dr Caroline Sangan, Dr Belinda Thompson and Mrs Francesca Thompson for their assistance in convening the Working Group whose scientific membership comprises: KESP (Chair), EMC (Vice-Chair), RLA, PB, PAB, NC, JSG, NCH, EPK, KAW and JEC (as Academy Chair). The authors are especially grateful for the contributions of the Patient Advocate Members of the Working Group; Ms Lois Ainger, Mrs Mary Bishop, Mr Nic Vine, and Mrs Karen Whitehead MBE

**Conflicts of Interest**

**-**

All other authors state they have no conflicts of interest.

Corresponding author email: kenneth.poole@nhs.net

**Abstract**

The growing burden from osteoporosis and fragility fractures highlights a need to improve osteoporosis management across healthcare systems. Sub-optimal management of osteoporosis is an area suitable for Digital Health Interventions. While Fracture Liaison Services (FLS) are proven to greatly improve care for people with osteoporosis, such services might benefit from technologies that enhance automation. The term ‘Digital Health’ covers a variety of different tools including Clinical Decision Support Systems, Electronic Medical Record tools, Patient Decision Aids, Patient apps, education tools, and novel artificial intelligence (AI) algorithms. Within the scope of this review are AI solutions that use algorithms within health systems registries to target interventions. Clinician‐targeted, patient-targeted or system-targeted Digital Health Interventions could be used to improve management and prevent fragility fractures.

This review was commissioned by The Royal Osteoporosis Society and Bone Research Academy during the production of the 2020 Research Roadmap (https://theros.org.uk), with the intention of identifying gaps where targeted research funding could lead to improved patient health. We explore potential uses of digital technology in the general management of osteoporosis.

Evidence suggests that digital technologies can support multidisciplinary teams to provide the best possible patient care based on current evidence and to support patients in self-management. However, robust randomised controlled studies are still needed to assess the effectiveness and cost-effectiveness of these technologies.

**1. Introduction and Background**

Digital Health Interventions aim to electronically connect points of care to provide easier and more secure sharing of relevant health and wellbeing data. Within the field of bone health such technologies encompass;

* Electronic patient records
* Clinical decision support systems
* Decision aids for patients
* Digital health supported patient communication
* Electronic mobile applications
* e-Triage
* e-Consult systems
* Digitally delivered osteoporosis education for clinicians
* Information for patients
* Artificial intelligence approaches to case-finding

In many countries, the embedding of digital technologies into healthcare is now seen as a priority and their use is encouraged by a range of government policy initiatives 1.

Osteoporosis is a disease characterised by reduced bone mass resulting in an increased risk of low-trauma fractures. These fragility fractures are associated with high morbidity and mortality as well as significant financial burden to health services worldwide2. Globally, 1 in 3 women over the age of 50 will experience fragility fractures, as will 1 in 5 men. In the UK it has been estimated that 3 million people have osteoporosis, with over 500,000 fragility fractures annually, costing the NHS £4.4 billion per year3. Meta-analyses confirm that individuals with prior fracture have a greatly increased risk of future fracture, independent of the risk attributable to low bone mineral density (BMD) or fracture site4. ‘Secondary prevention’ measures among people who have sustained a first fragility fracture; are seen as the key to avoiding significant and growing, economic and health burden of osteoporosis; and intervening in those people who have had a fracture is an area ripe for the application of Digital Health solutions. Although the precise nature of different FLS (Fracture Liaison Services) varies, a significant body of international evidence garnered over decades has demonstrated that FLS programmes are effective; increasing detection and overall management of osteoporosis; improving patient adherence to long-term treatment; improving post-fracture treatment, reducing recurrent fracture rates and saving hospital costs5,6,7,8,9,10,11. This includes level 1 evidence from systematic reviews with meta-analyses that FLS increase evaluation and treatment for osteoporosisincluding holistic care for the frail elderly after hip fracture12,13.

This is a ‘rapid evidence review’ and aims to provide a comprehensive review of the topic, it is not a full systematic review of all related literature. The recently published Cochrane guidance on the methodology of Rapid Review defines it as “A form of knowledge synthesis that accelerates the process of conducting a traditional systematic review through streamlining or omitting specific methods to produce evidence for stakeholders in a resource-efficient manner”14. Rapid evidence reviews are developed primarily by request for prompt evidence to help address urgent and emergent health issues deemed high priority14. With digital technology constantly evolving and the ever-growing burden of fragility fractures and osteoporosis to patients, this review was formulated as a repository of existing technologies as well as touching on future technologies.

It does not cover Artificial Intelligence methods for image analysis, covered in our separate review for the journal.

**2. Methodology:**

2.1 Data Sources

Data sources searched included:

· NICE Evidence library portal

· Systematic reviews via: Cochrane Library

· Electronic bibliographic databases: Embase, Medline; Tripdatabase; Web of Science

· Websites: NICE; NHS England and Improvement; King’s Fund; Nuffield Trust

· Search engines: Google Scholar and Google

· Theses and dissertations via: EThOS, PQDT Open, EBSCO Open Dissertations, NDLTD: Networked Digital Library of Theses and Dissertations, OATD: Open Access Theses and Dissertations, DART-Europe, Theses Canada, Trove

2.2 Search Strategy

A Boolean search strategy was applied using the operators AND, OR, NOT in combination with the following keywords; index headings and free text. Truncation techniques using asterisks and wildcard techniques using question marks were employed when free text searching:

“digital technolog\*” “digital solution\*” eHealth “digital health technolog\*” “digital health solution\*” “machine learning”, “cloud-based” “cloud computing” “Digital transformation”, “digital translation”, “information technolog\*”, “connected health”, app, “mobile application”, “mobile health application” “mobile phone”, “decision support”, “decision aid”, “electronic patient record\*,” “electronic health record\*”, reminder\*, alert\* “Fracture Liaison Service\*”, “fragility fracture\*”, osteoporosis, “care pathway” “treatment pathway”, “clinical pathway”

Additionally, reference lists of key relevant primary research, systematic reviews and meta-analyses and grey literature were examined to identify further studies. Citation searches of key relevant articles were undertaken. Targeted searches for publications by key academic researchers were made.

Searches were limited to English language.

**3. Findings:**

3.1 Digital Health – Definitions

The World Health Organization (WHO) definitions of digital health and digital health interventions states: *“The use of digital, mobile and wireless technologies to support the achievement of health objectives. Digital health describes the general use of information and communications technologies (ICT) for health and is inclusive of both mHealth (Mobile Health) and eHealth (Electronic Health) … the application of digital, mobile and wireless technologies for a defined health purpose, in order to address specific health system challenges.”* (Figure 1)15

![A screenshot of a social media post

Description automatically generated]()

**Figure 1: Sub-categories of Digital Health. Adapted from Deloitte UK (2015)16**

**3.2 Digital health in fracture risk assessment and osteoporosis identification**

Fracture risk-assessment tools such as the FRAX online calculator are the most obvious osteoporosis-specific application of Digital Health. Calculating an individuals’ 10-year risk of fracture is chiefly used to identify individuals who would benefit from osteoporosis treatment. Adoption, applicability and therefore effectiveness of FRAX in osteoporosis case finding is intrinsically limited by human factors; specifically the clinicians inclination to routinely manually enter clinical data and translate outputs into clinical practice. The National Osteoporosis Guidelines group (NOGG) have extended the utility of the FRAX Digital Health approach by electronically linking 10-year fracture risk values to agreed treatment thresholds, giving the clinician a simple visualization of whether to offer treatment or reassure17. One online alternative to FRAX, QFracture is fully integrated into the primary care digital system and automatically calculates fracture risk without need for manual data input, but is hampered by lack of bone density input and link to National Guidelines18. It does, however, try to permit patients to perceive their risk graphically by using basic ‘smiley’ face grids of 100, with adverse outcomes shown by coloured ‘unhappy’ faces. As we will highlight later, this area of helping patients perceive risk is central to osteoporosis and fragility fracture care, and ripe for the application of more sophisticated, useful Digital Health measures.

**3.2.1 Digital Health and improving Fracture Liaison Service Models**

There are now at least 225 FLS in over 35 countries (International Osteoporosis Foundation data)19 since the first successful demonstration of the clinical utility of this model of care in 199920.Despite differences between primary and secondary care models, a common factor within these programmes is they are usually coordinated by specified individual(s), usually clinical nurse specialists, who case-find, work to prescribed protocols with assistance and refer access to specialist clinicians21. Digital Health tools comprising reminders, risk assessment, or education can reduce secondary fracture rates and increase BMD investigations and the initiation of osteoporosis therapy 22, 23, 24, 25, 26, 27. Tools that target both clinicians and patients, and those that consist of multiple components (such as reminders and education) are associated with greater improvement in outcomes 26, 28, 29. Many of the evaluative RCTs 30, 31, 32 are of poor methodological quality, lacking the reporting of appropriately used methods of randomisation and its concealment, blinding, and follow-up in the studies.

The Fracture Liaison Service Database (FLS-DB) is an exemplar of Digital Health to support post-fracture care and reduce fracture risk, and is unique as a national patient-level audit. FLS-DB aims to measure the volume and quality of care in secondary fracture prevention delivery across England and Wales, having begun with a hip fracture specific database (which linked improved hip fracture management to financial incentives). High quality of care is achieved by facility and patient audits that aid identification of shortcomings in the service that can be altered or improved. It was commissioned by the Healthcare Quality Improvement Partnership (HQIP) as a new national audit as part of the Fragility Fracture Audit Programme (FFFAP) delivered by the Royal College of Physicians (RCP)33,34,35. From the 2020 RCP annual database report, 69 FLSs submitted patient data from over 180,000 patients in England and Wales. Local commissioners and FLSs can use the report results to improve post-fracture care delivery through service improvement and/or additional commissioning to reduce the number of preventable fragility fractures33. Limitations of FLS-DB are the necessity to manually upload patient level data, a shortcoming when very many variables are already captured in individual hospital-level electronic medical records. Linkage of EMR and FLS-DB would greatly facilitate utility.

MedCert FLS App introduced a digital ‘5i’ step approach (identify, inform, initiate, investigate and iterate) to the management of patients with fragility fracture in participating providers within the US and is an example of a secure, HIPAA (Health Insurance Portability and Accountability Act of 1996) compliant, cloud platform using software36. The software can support large numbers of concurrent users and can be easily accessed remotely through a device with internet access. It proved to be an effective method to monitor and treat patients following a fragility fracture. The app allows the FLS coordinator to monitor all patients at a glance; ensuring assessments and clinical reviews have not been missed.

The UK 2020 FLS-DB audit report37 recommended improved engagement with primary care to enhance monitoring of treatment adherence, vertebral fracture identification, and called for more timely access to DXA scans. Since FLS coordinator led care reduced re-fracture rates, improved surrogate measures (BMD testing rates; treatment initiation rates) and overall health costs, the system is an obvious target for the application of Digital Health21,38. Eventually, the ‘Internet of things’ (IoT) might prove useful in linking patients and their digital devices directly with FLS functions. This is particularly relevant to care of the elderly, whereby virtual and physical technologies such as sensors, actuators, and devices interacting wirelessly, could lead to health benefits such as falls prevention and medication adherence in older people39. Initial forays include an app which takes on some components of an FLS (patient-level reminders about fall prevention strategies, FRAX calculation, exercise and nutrition recommendations, recommendations to modify particular risk factors including sunshine exposure), but are at the experimental stage40. In the future, integration of, for example chair-based sensors, cameras, or real-time visualisation of balance are potential avenues to explore40 for falls prevention and fracture care in the elderly.

**3.2.2 Digital Health and osteoporosis identification, via clinician support systems, prompts and reminders**

A clinical decision support system (CDSS) is an aid for clinicians in their day-to-day decision making. They are primarily used at the point-of-care, where clinicians can combine their knowledge with information provided by web-applications, electronic health records (EHR) and computerized provider order entry (CPOE) systems. CDSS are typically accessed through desktop, tablet, smartphone and other devices41. A good example of a CDSS is the Icelandic Osteoporosis Advisor (OPAD), which helps identify individuals at increased risk of fracture, based on comprehensive guidelines and risk factors. OPAD prompts the clinician with primary prevention advice, evidence-based treatment recommendations and advice on follow-up 24,25. Prompts or alerts are part of common practice in primary care enabled through the use of EHR. There are integrated reminders within a CDSS. Evidence suggests that their use increases compliance with guideline practice27. Clinical decision support systems may also prove suitable for the application of logic-based Artificial Intelligence approaches42. Key limitations to CDSS adoption include the difficulty of integration with legacy and established EHRs and cost-effectiveness42.

A Cochrane review comprising 5 RCT’s and a meta-analysis reaffirmed the use of alerts in improving guideline practice31. Despite this, there is a lack of robust evidence on what types of alerts, reminders and prompts should be used and how they should be deployed to most positively impact practitioner practice and improve patient outcomes27. There are, however, examples of enhanced improvements in osteoporosis management using computerised system alerts23. A Canadian osteoporosis assessment tool, used in primary care settings, helps to screen and manage patients at point of care by nesting Canadian osteoporosis guidelines within the EHR system. By identifying and alerting clinicians to patients at risk of developing osteoporosis, improvements to the management of fragility fractures, supported proactive care and continued monitoring based on Canadian best practice recommendations are achievable 43.

**3.2.3 Digital Health and eConsultation/eTriage at the interface between primary and secondary care services**

In many countries, the demand for osteoporosis services exceeds the supply, resulting in limited access. The traditional approach of direct face-to-face clinical encounters is challenging, particularly with the coronavirus pandemic. Efficient referral management in high demand specialties is critical to ensure that the highest quality of care is provided. An electronic triage system via email for new outpatient referrals resulted in increased clinical efficiency and higher satisfaction for patients and health workers 44.

The Northern Ireland Electronic Health Care Record (NIECR) system has been adapted to include electronic triage and e-triage into the osteoporosis service. Its purpose is to streamline the screening process and address the extensive waiting times for access to medical services. The new service includes the option of ‘advice only’, direct to investigation with DXA or face-to-face appointments at the consultant-led complex osteoporosis service. There is a high degree of agreement for the triage category between the referring clinician and specialist services: 73.3% of patients attended a face-to-face appointment at the consultant-led clinic and active triage enabled investigation in 18.4% and discharge in 8.3%. This demonstrates that E-triage supports effective referral management in a busy osteoporosis service, with potential further improvement using greater multidisciplinary team access45. One limitation to the scaling up of such Digital Health innovations as NIECR, is the large variety and lack of national consensus in the optimal pathway; systems can be only adopted elsewhere if they can map to the NIECR model.

A large study performed in the US (2775 fracture episodes), with a centralised electronic triage system, enabled assessment of the cohort of individuals who lived in rural or highly rural areas (53.3% of total fracture episodes). The nurse liaison service significantly improved the rates of bisphosphonate prescription and BMD testing, for both urban and rural patients46. This study highlighted that despite the high demand on services, high quality care was provided, regardless of location, by optimising referral and screening systems.

More recently, NHSX partnered with Open Medical Ltd to produce [eTrauma](https://www.digitalmarketplace.service.gov.uk/g-cloud/services/529760955337699) software47, a cloud-based patient management system. The use of cloud-based, learning natural language processing algorithms, and structured granular datasets helped to improve data quality and by processing this detailed data, a new digital fracture liaison service model of care emerged. This automatically detects patients who may benefit from secondary osteoporosis prevention at the time of initial orthopaedic trauma referral. It is possible that this ‘data-driven’ care might improve identification of patients, enhance coordination and collaboration of teams (e.g., between fracture clinics and FLS) as well as increase the overall quality of patient care, but both clinical effectiveness and cost-effectiveness data are needed48.

**3.3 Use of Digital Health in patient decision making, communication and education:**

**3.3.1 Decision aids for patients and shared decision-making**

Shared decision making has never been more important than now in the field of osteoporosis treatment. The process by which a health care choice is made by the patient, family or carers, with one or more healthcare professionals is evolving, particularly in light of patient access to the ‘wild west’ of clinical and quasi-clinical information online49. While the medication leaflet must contain comprehensive information, and carefully curated evidence-based and balanced resources such as Royal Osteoporosis Society medication leaflets are universally distributed at the point of care, patients are increasingly likely to ‘do their own research online’ particularly in regard to rare and very rare osteoporosis drug side effects. This is where decision aids can be helpful as evidence-based tools to support shared decision-making in practice26. Particularly relevant to osteoporosis care is that these tools have been shown to improve the accuracy of patient risk perceptions. In osteoporosis this risk perception is key to whether a person feels willing to take a therapy to prevent a painful event that is in part due to chance (fragility fracture). Tools that are web-based can be rapidly updated and disseminated. When used appropriately such aids can improve patient-clinician rapport and as a result the development of an appropriate and open treatment plan, often with regard to commencement of drug treatment. An example of a decision aid is ‘The Osteoporosis Choice Decision Aid’ developed in 2008. It was designed for use by patients and their clinicians to facilitate shared decision-making. It incorporates a patient's 10-year risk probability of fracture estimated using the FRAX online calculator. It was compared in an RCT to usual care with and without the FRAX fracture risk, and it’s use reduced decisional conflict, increased treatment initiation, and improved patient knowledge and engagement50.

An important limitation to adoption is that some decision aids have been shown to make little or no difference to the number of healthcare professionals adhering to guideline practice and some aids have failed to meet international quality standards21, 51. Decision aids for patients are not always popular with patients; many patients still expect their physician or specialist to fulfil all the decision-making roles that such Digital Health technologies can enable52. Although patient decision aids seem promising for improving osteoporosis management, fundamental problems with available patient decision aids have been identified52, and it is critical that such aids use the best available evidence and/or have presented it appropriately.

**3.3.2 Digital Health-supported patient communication**

Most patients with osteoporosis want information about the condition, risk of fracture, treatment and understanding the role of BMD testing to enable self-management53. Interactive voice response (IVR) systems as well as more sophisticated forms of multimedia technologies to motivate and educate patients may have a role. Digital health interventions can range from simple voice call to more sophisticated application of multimedia technologies. A recent review concluded *“that a person-centred and integrated model of care can be delivered to older people with fragility fractures with the support of digital health technological solutions and achieve desired outcomes. Resources to optimise pain management, physical activity, nutrition, sleep hygiene and mental health could all be integrated. The provision of health information in isolation does not equate to education. Monitoring and feedback of progress are critical. Techniques such as behaviour change and motivational interviewing need to be integral to the service*”32. After the immediate discharge period, patients are often left alone to navigate the healthcare system leading to poorer post-fracture outcomes. Digital health studies should be undertaken with the intention of addressing broader populations with other complex diagnoses requiring more person-centred and integrated care32. An Interactive Voice Response (IVR) system developed in the US, screened high-risk postmenopausal osteoporotic women using a script lasting 4-5 minutes long. Compared to an RCT where educational packages were mailed to patients on top of their usual care, no clear benefit was seen 54. The diverse types of the tools available increase the difficulty in determining which tool is most effective.

**3.3.3 Digital Health supported professional clinical education**

A US model called Project ECHO (Extension for Community Healthcare Outcomes) is a technology-enabled collaborative learning system for healthcare workers in the management of skeletal diseases. Bone Health TeleECHO uses weekly videoconferencing to link healthcare professionals of varied experience and expertise to interact on the subject of osteoporosis55. Self-efficacy outcomes showed that regular Bone Health TeleECHO participants experienced a statistically significant improvement of confidence in managing each of 20 different domains of osteoporosis care 56. The ability to share knowledge and advice through videoconferencing technology allows for discussion of individualised treatment decisions outside of trust guidelines or personal preferences56.

**3.3.4 Digital Health supported patient education**

A multimodal, patient‐centred, tailored, video‐based behavioural intervention to encourage patients to seek osteoporosis diagnosis and treatment has been developed and evaluated in the Activating Patients at Risk for Osteoporosis (APROPOS) study. Intervention materials comprising personalised videos, were emailed to a personalised webpage and also mailed in a DVD format. The intervention also included follow-up telephone calls and IVR reminders to view the videos. At 6- and 18-month intervals there was no significant difference in rates of self-reported treatment initiation and follow up57. Multimedia as a patient education tool comprising learning modules with information on osteoporosis, risk factors, prevention and management by using a set of dramatised video clips is comparable to a printed booklet containing similar information58.

**3.4 Smartphone-based electronic mobile applications**

Mobile health (mHealth) is an ever-expanding area of health delivery and has the potential to complement other healthcare technologies. Mobile applications (apps) are used frequently in daily life, with over 100,000 accessible apps being health-care related59. Evidence suggests that mHealth apps improve symptom control through self-management and that these apps have the potential to improve health outcomes in those with chronic diseases59. However, there are relatively few specifically for osteoporosis and scarcequality control or regulation of app developers. The use of mHealth technology in relation to osteoporosis is expanding, but the value of these apps in this condition is under-evaluated60. Tables 1 and 2 show examples of mHealth apps either being tested or commercially available. Apps appear popular amongst users and there is some evidence to indicate that an older population would be willing to use them.

**Table 1: Example of Osteoporosis mHealth App**

|  |  |
| --- | --- |
| **App** | **Features** |
| FRAX App | The Fracture Risk Assessment Tool App (FRAX® App), developed by the Centre for Metabolic Bone Diseases at the University of Sheffield, UK, is an easy-to-use app to calculate an individual patient's 10-year probability of a major osteoporotic event (clinical spine, forearm, hip or shoulder fracture) and probability of an osteoporotic hip fracture from inputting simple clinical and demographic details. For use by clinicians, the App is PIN Protection for saved assessments, features Patient Results Management (save, delete & sort options) and  E-mail sharing capability of patient assessment (responses and results). |
| My Osteoporosis Journey - Denmark | For women with newly diagnosed asymptomatic osteoporosis. Aims to support patients in treatment decision making, self-management and used as an addition for healthcare workers in primary and secondary care61. Qualitative evidence suggested that the app reduced anxiety, gave patients more confidence and a feeling of reassurance. Achieved by allowing more control – test results to be seen before primary care physicians and support in self-management 62. |

**Table 2: Free Apps through search on App Store (Apple, California, USA)**

|  |  |
| --- | --- |
| **App** | **Features** |
| Hip Fracture Risk Calculator | A calculator for risk of hip fracture and risk of in-hospital mortality after hip fracture, based on patient demographics and comorbidities. Hip fracture risk calculation is based on Nguyen et al, Development of a nomogram for individualizing hip fracture risk in men and women, Osteoporosis Intl, 2007. |
| AACE Osteoporosis Treatment Algorithm | An algorithm which guides the user through the diagnosis and treatment options for postmenopausal osteoporosis based on guidelines developed by the American Association of Clinical Endocrinologists (AACE) |
| My Osteoporosis Manager @Point of Care | A management tool that enables patients with osteoporosis to track and store relevant health information between clinician visits. It includes the ability to capture detailed information regarding health in a digital journal; management of medications and treatments; tracking of osteo-specific symptoms and side effects; easy-to-understand charts that record test results and medication adherence; access to patient education materials; ability to share information with the patient’s healthcare provider |
| BoneGauge HarborLight Solutions LLC | This app allows the user to approximate an individual's bone density and quality from a mobile platform. It helps make measurements of cortical thickness of the second metacarpal from either hand or wrist X-rays from a photograph of an X-ray |

**3.5 Artificial Intelligence (AI), machine learning and their application to Electronic Health Records for falls and fracture risk prediction**

Computer based algorithms or prediction algorithms have been developed to identify fracture risk using different input datasets. They assist clinicians through calculation of 5- or 10-years risk of fracture based on known risk factors. There is no gold standard fracture assessment tool, although a recent systematic review suggests that QFracture, Fracture Risk Assessment Tool (FRAX) alongside BMD, and Garvan alongside BMD are the tools with the best discriminative ability61. A more efficient way to assess fracture risk would be from routinely available, easily accessible, population-based, administrative healthcare data. Data entry could be automated and integrated into EHRs, allowing risk assessment to be provided at the point of care hence guiding clinician management. Ideally this would be centralised and act as a screening tool for a wider population. Formulating fracture risk scores derived from information available in routine population-based healthcare data is of considerable interest. Using the power of large datasets and Artificial intelligence with Machine Learning to identify individuals at high risk of fracture from routinely acquired data is feasible. A Danish study describes the development and validation of a prediction model (FREM) for men and women at high risk of major osteoporotic fractures or hip fractures. It utilised administrative ICD‐10 data alone from public health registries with information on the total population aged 45 and older63. FREM lends itself to automation as it is driven entirely by routinely collected administrative data with no manual data entry at the point‐of‐service delivery. FREM found several recognised risk conditions for osteoporotic fractures, with age being the most important followed by a history of previous osteoporotic fractures at different locations and frailty or high risk of falls. The FREM tool and others like it are currently being evaluated for direct integration into EHR systems and nationwide patient information registries. Integration will automate the process, reducing reliance on human effort63, 64.

In the US, using EHR data and advanced machine learning algorithms, an EHR-based fall risk predictive model has been developed and validated to estimate a patient’s risk of falling within the following 12 months65. The algorithm, XGBoost, automatically integrates relevant information concerning disease diagnoses, medication use, clinical factors and laboratory test results to compute its prediction, and identify ‘high fall risk’ individuals. The model successfully captured 58.01 % and 54.93 % of falls that happened within 30 and 30–60 days of calculation. A total of 50% of the identified high-risk true positives were confirmed to fall during the first 94 days of the next year, indicating the model’s better performance for short-term fall prediction65.

**3.6 Use of digital technologies: a few words of caution**

Workforce implications

A recent national review66 makes recommendations concerning the creation of a digitally competent workforce, with three principles to support implementation of digital technology;

· Patients should be suitably informed about health technologies, with particular focus on vulnerable groups to ensure fair access

· The healthcare workforce needs knowledge and guidance to evaluate new technologies

· The adoption of technology should be used to give healthcare staff more time to care and interact directly with patients66.

Governance and Ethics

Using artificial intelligence in clinical practice comes with an additional set of challenges, and has huge implications for accountability, regulation, governance, and ethics. It has been suggested that the four primary ethical challenges are informed consent to use, safety and transparency, algorithmic fairness and biases, and data privacy67. “*Regulating algorithms in healthcare*”, a project led by the PHG Foundation, University of Cambridge, focused on how algorithms in healthcare are currently regulated. They made recommendations for improvement to ensure a suitable balance between the need for medical innovation and patient safety68, 69.

**Conclusion**

Development and implementation of digital technology is increasing rapidly. Healthcare departments are keen to partner with academics, industry and the commercial sector in order to deliver trustworthy digital solutions to improve patient care. Evidence suggests that digital technologies can support multidisciplinary teams to provide the best possible patient care based on current evidence and to support patients in self-management. Two factors need to be considered; 1) the methodological quality of many of the studies that evaluate these technologies is low, limiting validity and 2) most studies have been undertaken in a variety of global settings. Therefore, robust randomised controlled studies are still needed to assess the effectiveness and cost-effectiveness of these technologies, particularly in mHealth. Finally, in order for technology to be embraced and embedded in practice, it is important to have a digitally competent workforce who can effectively use these technologies.

**References**

1 - Mathews, S.C., McShea, M.J., Hanley, C.L. *et al.* Digital health: a path to validation. *npj Digit. Med.* **2,** 38 (2019). https://doi.org/10.1038/s41746-019-0111-3

2 – Svedbom A, Hernlund E, Ivergård Met al 2013 Osteoporosis in the European Union: a compendium of country-specific reports. Archives of osteoporosis 8(1-2):137

3- 1. 2018 NICE impact report on falls and fragility fractures. British Geriatrics Society. 2020;-(-):-.

4. Kanis JA, Johnell O, De Laet C, et al. A meta-analysis of previous fracture and subsequent fracture risk. Bone. 2004;35:375–382

5 - McLellan AR, Wolowacz SE, Zimovetz EA et al 2011 Fracture liaison services for the evaluation and management of patients with osteoporotic fracture: a cost-effectiveness evaluation based on data collected over 8 years of service provision. Osteoporos Int 22:2083–2098

6 - Eisman JA, Bogoch ER, Dell R 2012 Making the first fracture the last fracture: ASBMR task force report on secondary fracture prevention. J Bone Miner Res 27(10): 2039–2046

7 - Mitchell PJ 2013 Best practices in secondary fracture prevention: fracture liaison services. Curr Osteoporos Rep 11(1): 52–60

8 - Akesson K, Marsh D, Mitchell PJ 2013 Capture the fracture: a best practice framework and global campaign to break the fragility fracture cycle. Osteoporosis Int 24(8):2135–2152

9 - Geusens P, Bours SP, Wyers CE et al 2019 Fracture liaison programs. Best Practice & Research Clinical Rheumatology 33(2): 278-289

10 - Nakayama A, Major G, Holliday E et al 2016 Evidence of effectiveness of a fracture liaison service to reduce the re-fracture rate. Osteoporos Int 27(3): 873-879

11 - Axelsson KF, Johansson H, Lundh D et al 2020 Association Between Recurrent Fracture Risk and Implementation of Fracture Liaison Services in Four Swedish Hospitals: A Cohort Study. Journal of Bone and Mineral Research doi:10.1002/jbmr.3990

12 -Geusens P, Bours SP, Wyers CE et al 2019 Fracture liaison programs. Best Practice & Research Clinical Rheumatology 33(2): 278-289

13 - Wu CH, Tu ST, Chang YF et al 2018 Fracture liaison services improve outcomes of patients with osteoporosis-related fractures: a systematic literature review and meta-analysis. Bone 111: 92–100

14 - Garritty C, Gartlehner G, Kamel C, King VJ, Nussbaumer-Streit B,. Stevens A, Hamel C, Affengruber L. Cochrane Rapid Reviews. Interim. Guidance from the Cochrane Rapid Reviews Methods Group. March 2020

15 - Monitoring and evaluating digital health interventions: a practical guide to conducting research and assessment. Geneva: World Health Organization; 2016. Licence: CC BY-NC-SA 3.0 IGO.

16- Deloitte 2018. 2018 Global health care outlook: The evolution of smart health care. Available:<https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Life-Sciences-Health-Care/gx-lshc-hc-outlook-2018.pdf> [Accessed December 2020]

17 - Kanis JA, Johansson H, Harvey NC, Lorentzon M, Liu E, Vandenput L, McCloskey EV. An assessment of intervention thresholds for very high fracture risk applied to the NOGG guidelines : A report for the National Osteoporosis Guideline Group (NOGG). Osteoporos Int. 2021 Oct;32(10):1951-1960. doi: 10.1007/s00198-021-05942-2. Epub 2021 Apr 4. PMID: 33813622.

18 - Kanis, J. A., Harvey, N. C., Johansson, H., Odén, A., McCloskey, E. V., & Leslie, W. D. (2017). Overview of Fracture Prediction Tools. Journal of clinical densitometry : the official journal of the International Society for Clinical Densitometry, 20(3), 444–450. <https://doi.org/10.1016/j.jocd.2017.06.013>

19 - Geusens P, Bours SP, Wyers CE et al 2019 Fracture liaison programs. Best Practice & Research Clinical Rheumatology 33(2): 278-289

20 - McLellan AR, Gallacher SJ, Fraser M et al 2003 The fracture liaison service: success of a program for the evaluation and management of patients with osteoporotic fracture. Osteoporos Int 14(12): 1028–1034

21 - Ganda K, Puech M, Chen JS, Speerin R, Bleasel J, Center JR, Eisman JA, March L, Seibel MJ. Models of care for the secondary prevention of osteoporotic fractures: a systematic review and meta-analysis. Osteoporos Int. 2013 Feb;24(2):393-406. doi: 10.1007/s00198-012-2090-y. Epub 2012 Jul 25. PMID: 22829395.

22 - Merlijn T, KMA S, van der Horst HE et al 2019 Fracture prevention by screening for high fracture risk: a systematic review and meta-analysis. Osteoporos International. 14:1-7

23 - Goldshtein I, Shamai-Lubovitz O, Guindy M et al 2020 Development and efficacy of a computerized decision support system for osteoporosis management in the community. Archives of Osteoporosis. 15(1): 1-7

24 - Halldorsson BV, Bjornsson AH, Gudmundsson HT et al 2015 A clinical decision support system for the diagnosis, fracture risks and treatment of osteoporosis. Comput Math Methods Med. 9: 1–7

25 - Gudmundsson HT, Hansen KE, Halldorsson BV et al 2019 Clinical decision support system for the management of osteoporosis compared to NOGG guidelines and an osteology specialist: a validation pilot study. BMC medical informatics and decision making. 19(1): 1-8

26 - Paskins Z, Torres Roldan VD, Hawarden AW, Bullock L, Meritxell Urtecho S, Torres GF, Morera L, Espinoza Suarez NR, Worrall A, Blackburn S, Chapman S, Jinks C, Brito JP. Quality and effectiveness of osteoporosis treatment decision aids: a systematic review and environmental scan. Osteoporos Int. 2020 Oct;31(10):1837-1851. doi: 10.1007/s00198-020-05479-w. Epub 2020 Jun 5. PMID: 32500301.

27 - Backman, R., Bayliss, S., Moore, D. et al. Clinical reminder alert fatigue in healthcare: a systematic literature review protocol using qualitative evidence. Syst Rev 6, 255 (2017). <https://doi.org/10.1186/s13643-017-0627-z>

28 - Britnell M, Bakalar R, Shehata A. Digital health: heaven or hell. How technology can drive or derail the quest for efficient, high quality healthcare. Zürich: KPMG International. 2016

29 - ​​Stacey D, Légaré F, Lewis K et al 2017 Decision aids for people facing health treatment or screening decisions. Cochrane Database of Systematic Reviews Issue 4. Art. No.: CD001431. DOI: 10.1002/14651858.CD001431.pub5.

30 - Gadkari AS, McHorney CA 2010 Medication nonfulfillment rates and reasons: narrative systematic review. Curr Med Res Opin 26: 683–705

31 - Tzortziou Brown V, Underwood M, Mohamed N et al 2016 Professional interventions for general practitioners on the management of musculoskeletal conditions. Cochrane Database Syst Rev. (5):CD007495.

32 - Yadav L, Haldar A, Jasper U et al 2019 Utilising digital health technology to support patient-healthcare provider communication in fragility fracture recovery: systematic review and meta-analysis. International journal of environmental research and public health. 16(20): 4047 p. 20

33 - Royal College of Physicians. Fracture Liaison Service Database (FLS-DB). 2019 Available<https://www.rcplondon.ac.uk/projects/fracture-liaison-service-database-fls-db> [Accessed January 2021]

34 - Mitchell PJ, Cooper C, Fujita M et al 2019 Quality improvement initiatives in fragility fracture care and prevention. Current osteoporosis reports 17(6):510-20

35 - Gallagher C, Vasilakis N, Javaid K. Fracture Liaison Services in England and Wales, inequity of access and quality of care after a fragility fracture. Clin Med (Lond). 2019;19(Suppl 2):77. doi:10.7861/clinmedicine.19-2-s77

36 - Holzmueller CG, Karp S, Zeldow D et al 2016 Development of a cloud-based application for the Fracture Liaison Service model of care. Osteoporosis International. 27(2): 683-690

37 - Royal College of Physicians FLS database annual report 2020 [Accessed Jan 2021]

38 - Walters S, Khan T, Ong T 2017 Fracture liaison services: improving outcomes for patients with osteoporosis, Clin. Interv. Aging 12: 117–127

39 - L. Atzori, A. Iera and G. Morabito, "The Internet of Things: A survey", Comput. Netw., vol. 54, no. 15, Oct. 2010.

40 - Kim SW, Won Y-J, Chae D-S et al 2019 A New Fracture Liaison Service Using the Mobile Application and IoT Sensor. Conf Proc IEEE Eng Med Biol Soc 3486-3489

41 - Dias, D. Wearable health devices—vital sign monitoring, systems and technologies. <https://doi.org/10.3390/s18082414> (2018).

42 - Sutton, R.T., Pincock, D., Baumgart, D.C. et al. An overview of clinical decision support systems: benefits, risks, and strategies for success. npj Digit. Med. 3, 17 (2020). <https://doi.org/10.1038/s41746-020-0221-y>

43 - Health Centre of Excellence Osteoporosis Disease Risk: A case study on assessing patients’ risk for osteoporosis, facilitating proactive care 2020 [Accessed Jan 2021]

44 - Patterson V, Humphreys J, Chua R 2004 Email triage of new neurological outpatient referrals from general practice. J Neurol Neurosurg Psychiatry 75(4): 617–620

45 - Lindsay, J. R., Lawrenson, G., & English, S. (2020). A service evaluation of e-triage in the osteoporosis outpatient clinic-an effective tool to improve patient access?. Archives of osteoporosis, 15(1), 53. <https://doi.org/10.1007/s11657-020-0703-1>

46 - Lee RH, Lyles KW, Pearson M et al 2014 Osteoporosis screening and treatment among veterans with recent fracture after implementation of an electronic consult service. Calcif Tissue Int 94(6): 659–664

47 - Open Medical Ltd eTrauma. [Accessed Jan 2021]

48 - Open Medical Ltd Virtual clinics. [Accessed Jan 2021]

49 - Légaré F, Adekpedjou R, Stacey D et al 2018 Interventions for increasing the use of shared decision making by healthcare professionals. Cochrane Database of Systematic Reviews Issue 7. Art. No.: CD006732. DOI: 10.1002/14651858.CD006732.pub4

50 - LeBlanc A, Wang AT, Wyatt K et al 2015 Encounter decision aid vs. clinical decision support or usual care to support patient-centered treatment decisions in osteoporosis: the osteoporosis choice randomized trial II. PloS one. 10(5): e0128063

51 - Fønhus MS, Dalsbø TK, Johansen M, Fretheim A, Skirbekk H, Flottorp SA. Patient-mediated interventions to improve professional practice. Cochrane Database Syst Rev. 2018 Sep 11;9(9):CD012472. doi: 10.1002/14651858.CD012472.pub2. PMID: 30204235; PMCID: PMC6513263.

52 - Paskins Z, Worrall A, Chapman S 2018 Patient and public views of bisphosphonate decision aids: Not fit for purpose. Osteoporosis International 29(1)

53 - Raybould G, Babatunde O, Evans AL et al 2018 Expressed information needs of patients with osteoporosis and/or fragility fractures: a systematic review. Arch Osteoporos 13(1): 55

54 - Heyworth L, Kleinman K, Oddleifson S et al 2014 Comparison of interactive voice response, patient mailing, and mailed registry to encourage screening for osteoporosis: a randomised controlled trial. Osteoporosis International 25(5): 1519–1526

55 - Lewiecki EM, Jackson A, Lake AF et al 2019 Bone Health TeleECHO: a Force Multiplier to Improve the Care of Skeletal Diseases in Underserved Communities. Current osteoporosis reports.17(6): 474-482

56 - Lewiecki EM, Rochelle R, Bouchonville MF 2nd et al 2017 Leveraging scarce resources with bone health TeleECHO to improve the care of osteoporosis. J Endocr Soc. 1(12): 1428–1434

57 - Danila MI, Outman RC, Rahn EJ et al 2016 A multi‐modal intervention for Activating Patients at Risk for Osteoporosis (APROPOS): rationale, design, and uptake of online study intervention material. Contemp Clin Trials Commun. 4: 14–24

58 - Danila MI, Outman RC, Rahn EJ 2018 Evaluation of a multimodal, direct‐to‐patient educational intervention targeting barriers to osteoporosis care: a randomized clinical trial. Journal of Bone and Mineral Research. 33(5): 763-772

59 - Whitehead, L., & Seaton, P. (2016). The Effectiveness of Self-Management Mobile Phone and Tablet Apps in Long-term Condition Management: A Systematic Review. Journal of medical Internet research, 18(5), e97. https://doi.org/10.2196/jmir.4883

60 - Slomian J, Appelboom G, Ethgen,O et al 2014 Can new information and communication technologies help in the management of osteoporosis? Women's Health 10: 229–232

61 - Beaudoin C, Moore L, Gagné M et al 2019 Performance of predictive tools to identify individuals at risk of non-traumatic fracture: a systematic review, meta-analysis, and meta-regression. Osteoporosis International. 30(4): 721-740

62 - Ravn Jakobsen P, Hermann AP, Søndergaard J et al 2018 Help at hand: Women’s experiences of using a mobile health application upon diagnosis of asymptomatic osteoporosis. SAGE Open Medicine. 6: 2050312118807617

63 - Rubin KH, Möller S, Holmberg T et al 2018 A new fracture risk assessment tool (FREM) based on public health registries. Journal of Bone and Mineral Research 33(11): 1967-1979

64 - Yang S, Leslie WD, Morin SN et al 2018 Administrative healthcare data applied to fracture risk assessment. Osteoporosis International. 30(3): 565-571

65 - Ye C, Li J, Hao S et al 2020 Identification of elders at higher risk for fall with statewide electronic health records and a machine learning algorithm. International journal of medical informatics. 3:104105

66 - Topol E. The Topol review: preparing the healthcare workforce to deliver the digital future. Health Education England. 2019

67 - Lewiecki EM, Rudolph LA, Kiebzak GM et al 2006 Assessment of osteoporosis-website quality. Osteoporosis International 17: 741–752

68 - Mack DE, Wilson PM, Crouch M et al 2016 Evaluating the quality and accuracy of online physical activity resources for individuals living with osteoporosis. Educational Gerontology 42(5): 321-329

67 - Gerke S, Minssen T, Cohen IG. Ethical and Legal Challenges of Artificial Intelligence-Driven Health Care. Forthcoming in: Artificial Intelligence in Healthcare, 1st edition, Adam Bohr, Kaveh Memarzadeh (eds.). 2020

68 - PHG Foundation website: Regulating algorithms in healthcare [Accessed Jan 2021]

69 - PHG Foundation Algorithms as medical devices 2019 [Accessed Jan 2021]