EClinicalMedicine 38 (2021) 101022

Contents lists available at ScienceDirect

EClinicalMedicine

journal homepage: https://www.journals.elsevier.com/eclinicalmedicine

Models of care for osteoporosis: A systematic scoping review of efficacy and implementation characteristics

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ARTICLE INFO

Article History:
Received 21 May 2021
Revised 21 June 2021
Accepted 25 June 2021
Available online xxx

ABSTRACT

Background: Osteoporosis affects over half of adults over 50 years worldwide. With an ageing population, osteoporosis, fractures and their associated costs are increasing. Unfortunately, despite effective therapies, many with osteoporosis remain undiagnosed and untreated. Models of care (MoC) to improve outcomes include fracture liaison services, screening, education, and exercise programs, however efficacy for these is mixed. The aim of this study is to summarise MoC in osteoporosis and describe implementation characteristics and evidence for improving outcomes.

Methods: This systematic scoping review identified articles via Ovid Medline and Embase, published in English between 01/01/2009 and 15/06/2021, describing MoC for adults aged ≥18 years with, or at risk of, osteoporosis and / or health professionals caring for this group. All included at least one of clinical, consumer or clinician outcomes, with fractures and bone mineral density (BMD) change the primary clinical outcomes. Exclusion criteria were studies assessing pharmaceuticals or procedures without other interventions, or insufficient operational details. All study designs were included, with no comparator necessary. Title and abstract were reviewed by two reviewers. Full text review and data extraction was performed by these reviewers for 20% of article and, thereafter by a single author. As the review was predominantly descriptive, no comparator statistics were used.

Findings: 314 articles were identified describing 289 MoC with fracture liaison services (*n*=89) and education programs (*n*=86) predominating. The population had prior fragility fracture in 77 studies, the median (IQR) patient number was 210 (87, 667) and the median (IQR) follow-up duration for outcome assessment was 12 (6, 12·5) months. Fracture reduction was reported by 65 studies, with 16 (37%) graded as high quality, and 19 / 47 studies with a comparator group found a reduction in fractures. BMD change was reported by 73 studies, with 41 finding improved BMD. Implementation characteristics including reach, fidelity and loss to follow-up were under-reported, and consumer and clinician perspectives rare.

Interpretation: This comprehensive review of MoC for osteoporosis demonstrated inconsistent evidence for improving outcomes despite similar types of models. Future studies should include implementation outcomes, consumer and clinician perspectives, and fracture or BMD outcomes with sufficient duration of follow-up. Authors should consider pragmatic trial designs and co-design with clinicians and consumers.

1. Introduction

Osteoporosis and low bone mass (osteopenia) is estimated to effect more than 50% of adults aged over 50 years [1,2]. Osteoporosis causes minimal symptoms prior to a fracture, and, in older adults, most fractures are the result of osteoporosis [3,4]. In 2000, 9 million osteoporotic fractures occurred worldwide; the lifetime risk of hip fracture for adults aged 50 years is equivalent to the risk of stroke, and the risk of any major osteoporotic fracture is similar to the risk of cardiovascular disease [5,6]. Morbidity and mortality following fracture is substantial, and recent evidence suggests the burden from osteoporotic fractures is greater than many other non-communicable diseases, including chronic obstructive pulmonary disease and stroke [5]. The cost to the healthcare system for fractures is large; among six European countries, expenditure on osteoporotic fractures was €37.5 billion in 2017, or up to 6.4% of healthcare expenditure [5].

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https://doi.org/10.1016/j.eclinm.2021.101022

Research in context

Evidence before this study

Models of care for improving outcomes for people with, or at risk of, osteoporosis include fracture liaison, screening, education and exercise programs. However, the evidence for improving clinical outcomes is mixed, and there is a paucity of data on the most critical outcome of fracture reduction. We performed a systematic scoping review of models of care for adults with or at risk of osteoporosis, using Ovid Medline and Ovid Embase, of articles published between 01/01/2009−15/06/2021.

Added value of this study

To our knowledge, this is the largest review of models of care in osteoporosis. We have provided a comprehensive summary of published evidence and have used a validated system for classifying models of care, which can be replicated in other studies.

Implications of all the available evidence

We suggest future reports on models of care for osteoporosis consider the study design, and inclusion of an appropriate comparison group, provide longitudinal follow-up to allow assessment of fracture reduction, or consider using bone mineral density changes as a surrogate marker for this, and include details of delivery and implementation characteristics, which may assist in scaling models to other settings. Lastly, we suggest the inclusion of consumer or clinician perspectives, as key to the success of complex interventions.

With an ageing population worldwide, the prevalence of osteoporosis, low bone mass, and osteoporotic fractures is predicted to increase, and by 2040 it is expected that over 300 million people will be at high risk for osteoporotic fracture [7]. Therefore, it is critical that measures are taken to prevent fractures, and ensure that people who suffer a fracture receive appropriate care to prevent recurrent fractures. Unfortunately, a treatment gap exists in osteoporosis, with low screening and treatment rates, and poor adherence to treatment [5,8−10]. Models of care (MoC) can be defined as operationalising how specific care should be delivered to a group of people at a disease, service or systems level [11]. MoC for primary fracture prevention include screening, education initiatives for clinicians and / or consumers, and exercise programs [12−14]. The efficacy of these initiatives is unclear, and may be related to differences in program characteristics, the population studied, and control group used [13,15,16]. The gold standard MoC for secondary prevention of osteoporotic fractures is a fracture liaison service (FLS). An FLS employs a dedicated coordinator to identify, inform and assess all patients with an osteoporotic fracture within a health system. Different FLS have been classified as Type A (identify patients, investigate for secondary causes of osteoporosis and initiate appropriate treatment), Type B (identify and investigate, but refer to primary care physician for treatment), Type C (identify and inform patient and their primary care physician) and Type D (identify and inform the patient only) [17]. Reviews of FLS have shown an improvement in dual energy X-ray absorptiometry (DXA) screening and treatment rates, which vary by the type of FLS model, being highest for the Type A FLS model [16−19]. Whilst increased treatment may be presumed to lead to a reduction in refractures due to the known benefits of antiresorptive therapy, adherence to treatment started in an FLS is variable, ranging between 34 and 95% [17]. Indeed, evidence for fracture reduction using an FLS is unclear, limited by study size, an appropriate control group and duration of follow-up [17]. Recently, changes in bone mineral density (BMD) has been proposed as a surrogate marker for fractures for therapeutic trials in osteoporosis, and this may also prove useful for more complex interventions such as FLS [20].

A limitation of published research on osteoporosis MoC is failure to include delivery and implementation characteristics. Operational characteristics for delivery include the frequency, duration and method of contact, the setting, and whether participants are seen individually or in a group. Implementation characteristics include factors such as acceptability, uptake, fidelity, cost and sustainability [21]. Studies of osteoporosis MoC can be viewed as hybrid effectiveness-implementation trials, as they use a targeted implementation strategy (such as education or coordination of care) to try to change behaviour (such as medication initiation, DXA screening) and ultimately improve bone health (reduce fractures or increase BMD). Guidelines exist on designing and reporting on implementation trials, and frameworks such as RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance) can be used to assess and compare implementation characteristics in real-world interventions [22−24]. Differences in implementation characteristics may contribute to variable outcomes between similar MoC, and impact the ability to scale up MoC to other settings.

Despite advances in screening and treatment for osteoporosis, a global increase in fractures in the coming years due to populations ageing is predicted, and so implementing effective models of care is essential [5,25,26]. The aims of this review are to: (i) summarise MoC for people with or at risk of osteoporosis; (ii) outline and compare the implementation characteristics of different MoC; and (iii) compare whether different MoC improve a variety of outcomes including reductions in fractures and increases in BMD. We hope this will assist those people planning, implementing and reporting on osteoporosis interventions in the future.

2. Methods

2.1. Search strategy and selection criteria

A scoping review methodology was chosen to enable a broad overview of MoC that have been trialled in osteoporosis, and to describe the evidence for each of these. The scoping review protocol adhered to the Joanna Briggs Institute guidelines for scoping reviews [27]. Inclusion criteria were English language publications, published between 01/01/2009 and 15/06/2021. This date range was chosen to include the most contemporary MoC using currently available technology and therapeutics. All study designs were included. The population was defined as either (i) adults aged ≥18 years with, or at risk of, low bone mineral density with or without fracture; and / or (ii) any health professional, including allied health. The intervention comprised any MoC for osteoporosis. No comparator was necessary for inclusion. Outcomes needed to include at least one of clinical, consumer or clinician outcomes. The primary clinical outcome was fractures; the secondary clinical outcome was increase in BMD. Other outcomes included consumer (medication use and adherence, calcium supplement use / calcium intake, vitamin D supplement use, DXA rates, osteoporosis knowledge, osteoporosis self-efficacy, osteoporosis health beliefs), clinician (prescribing rates for medications and vitamin D, screening rates for DXA, osteoporosis knowledge), health service satisfaction, implementation characteristics and cost. Implementation characteristics were broadly based on the RE-AIM framework [24]-Reach (the proportion of people who participated in the MoC, of those eligible), Effectiveness (outcomes as mentioned), Adoption (where applicable, the proportion of settings / institutions who participated in the MoC, of those invited), Implementation (fidelity to the intervention) and Maintenance (the longest time point reported was included in results). Exclusion criteria were studies assessing individual or combination pharmaceuticals or procedures

without other interventions, or insufficient detail provided to specify operational characteristics of the MoC.

A systematic search, based on the selection criteria and combining MeSH terms and text words, was developed for Ovid Medline and translated to Embase (Supplement 1). Hand searching of included articles' reference lists was also performed. Authors were contacted directly where full-text article could not be retrieved, or to clarify study details. Covidence (www.covidence.org) was used to manage search results, and for abstract and full text review. Two reviewers (AJ, MH) independently reviewed the titles, abstracts and keywords of every article retrieved by the search strategy according to the selection criteria. Full text of the articles were retrieved for further assessment if the information given suggests that the study meets the selection criteria or if there is any doubt regarding eligibility of the article based on the information given in the title and abstract. Full text review and data extraction was performed independently by two reviewers for 20% of articles, to achieve 100% agreement, thereafter performed by a single author (AJ). The study protocol was registered with Joanna Briggs Scoping reviews on 13/11/2019 (Supplement 2), and reporting adhered to the PRISMA-scoping review extension checklist.

2.2. Data analysis

Data extraction was performed in Microsoft Excel 2016. We adapted our data extraction table from the Cochrane Effective Practice and Organisation of Care (EPOC) framework for describing interventions, and a previously published scoping review on low-cost MoC [28,29]. Information collected included general details (title, authors, country, year of publication), participants and number, the MoC implemented, delivery characteristics [28] (contact method, frequency, setting, individual vs group care) and clinical outcomes as mentioned. MoC were categorized according to the Cochrane EPOC taxonomy of delivery arrangements and implementation strategies for health system interventions [30]. We also classified MoC by the primary type of activity, such as fracture liaison services (further classified into Types A to D as per Ganda [17], education, exercise, screening, orthogeriatric services (OGS), or specialist review. Where models were multi-component, the primary activity was listed, followed by the other types. Where a single model, with the same participants, was described by different papers (Eg. different time points or outcomes), results were summarised together. The longest follow up time point reported was included in result tables. Where studies included a comparison group, p values for between groups, was included in results tables. Due to the number of studies included in our review, risk of bias assessment using the SIGN proforma [31], was performed for papers reporting fractures, our primary clinical outcome, only.

Given the primary aim of this review was descriptive, no comparative statistics were used. Categorical data are described as number (percentage, %). Continuous data are described as mean (standard deviation) where normally distributed, and median (interquartile range, IQR) when non-parametric. Studies were summarised (i) overall, and then by outcomes of (ii) fractures and (iii) BMD change.

2.3. Role of the funding source

This study received no direct funding. All authors had full access to the data in the study and accept responsibility to submit for publication.

3. Results

3.1. Overall

Fig. 1 and Supplement 3 summarises our search strategy, which resulted in 314 articles included which reported on 289 models of care (25 articles were additional follow-up of the same model and participants). The majority of excluded studies at the title and abstract stage reported only on pharmaceuticals / surgical procedures, and at the full text review stage because they were an abstract only or reported the wrong outcomes.

Summary data for included studies are shown in Table 1, with complete study details shown in Table S1 and implementation characteristics are in Table 2.

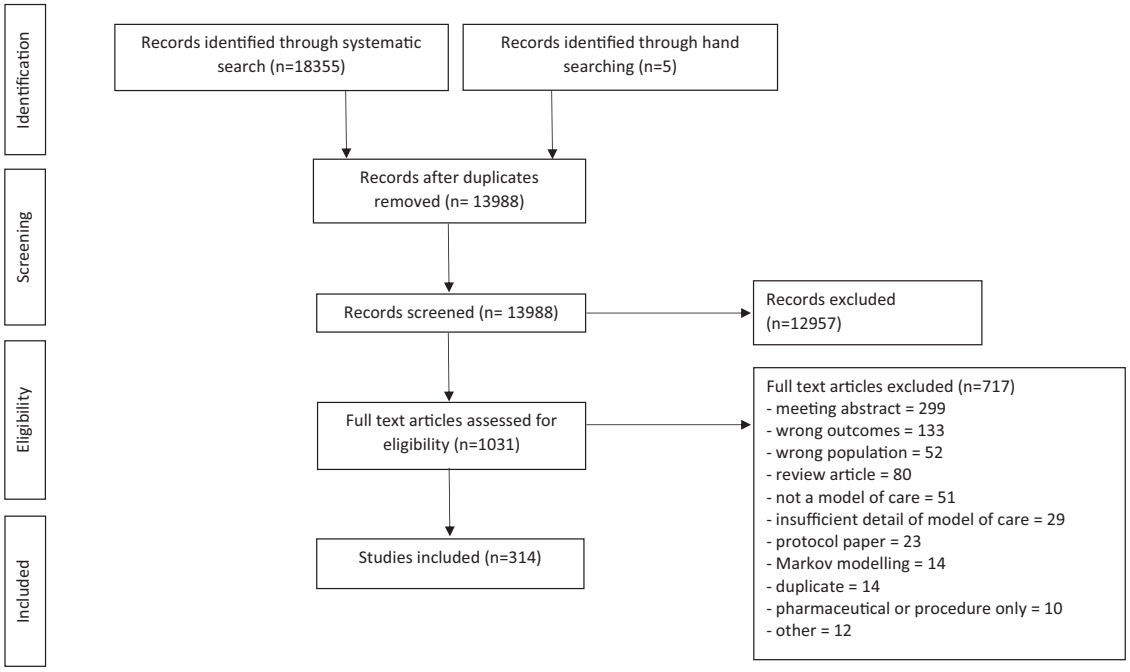

Fig. 1. Study selection.

Table 1.
Summary characteristics of included studies.

Study design *n*(%)		Randomised trial	117 (40·5)
		Non-randomised trial	16 (5·5)
		Cohort study	80 (27·7)
		Case study / series	38 (13·1)
		Pre-test post-test	23 (8·0)
		Other	15 (5·2)
Type of model of care n(%)		Education	86 (29·8)
		Fracture liaison service	89 (30·8)
		Type A	54 (18·7)
		Type B	13 (4·5)
		Type C	15 (5·2)
		Type D	4 (1·4)
		Combination	3 (1·0)
		Exercise	68 (23·5)
		Screening	18 (6·2)
		Orthogeriatric service	11 (3·8)
		Other	17 (5·9)
Target Population *n*(%)	Patient (*n*=290)	Prior fragility fracture (any)	77 (26·6)
		Post-menopausal women	44 (15·2)
		Prior hip fracture	38 (13·1)
		Older adults	30 (10·4)
		Postmenopausal women with low BMD	27 (9·3)
		Known low BMD	18 (6·2)
		Females with cancer	9 (3·1)
		Prior radius fracture	7 (2·4)
		Males with prostate cancer	6 (2·1)
		Other	33 (11·4)
	Clinician (*n*=42)	Primary care physicians	23 (54·8)
		Specialist physicians	4 (9·5)
		orthopaedic surgeons	4 (9·5)
		Junior doctors	4 (9·5)
		Other	7 (16·7)
Outcomes *n*(%)*	Patient level	Fractures	65 (22·5)
		BMD	73 (25·3)
		DXA	87 (30·1)
		Treatment (antiresorptive / anabolic)	113 (39·1)
		Vitamin D	38 (13·1)
		Calcium intake (supplement+/- diet)	56 (19·4)
		Osteoporosis knowledge	32 (11·1)
		Osteoporosis self-efficacy	14 (4·8)
		Osteoporosis health beliefs	9 (3·1)
	Clinician level	Ordering DXA	21 (7·3)
		Prescribing (antiresorptive / anabolic)	48 (16·6)
		Prescribing Vitamin D	7 (2·4)
		Osteoporosis knowledge	1 (0·3)

Footnote: BMD: bone mineral density; DXA: dual energy X-ray absorptiometry; *n>289 and percentages add to >100% as studies may have more than one outcome.

3.2. MoC classification

The majority of studies used the EPOC delivery arrangement 'coordination of care and management of care processes' (*n*=177, 61·2%, Table 2), 15 studies compared different delivery arrangements and four studies included more than one subcategory. The most common EPOC implementation strategy was 'interventions targeted at specific types of practice, conditions or settings', observed in 198 studies (68·5%), all of which targeted specific conditions, eight studies compared different implementation strategies, and 25 included more than one subcategory. Classifying MoC by activity, the most common MoC was FLS (*n*=89, 30·8%), of which the majority (*n*=54) were classified as a Type A (Table 1). The second most common activity was education (*n*=86, 29·8%), of these 52 targeted patients with eight also sending written communication to a clinician, 24 targeted clinicians only, and 27 targeted both patients and clinicians. In addition, 17 studies included an educational component within another MoC. 32 studies were multi-component (included more than one type of MoC), most commonly screening with education (*n*=8, 2·8%).

3.3. Study characteristics (Tables 1 and S1)

Most studies were from North America (*n*=123, 42·6%) or Europe (*n*=77, 26·6%) (Table S1). Study designs varied with randomised trials predominating (Table 1), however 30 of these did not report the randomisation method used. All studies targeted a patient population. The median (IQR) number of participants was 210 (87, 667), ranging from 13 to 650,000. While 42 studies targeted clinicians, only 14 (33·3%) of studies reported the number of clinicians involved. The median (IQR) number of clinicians was 57 (24, 327), ranging from 5 to 31,459. The median (IQR) follow-up duration for outcome assessment was 12 (6, 12·5) months, and 130 (45%) of studies had follow-up of ≤6 months.

3.4. Implementation characteristics (Table 2)

The majority of studies delivered the MoC in a face-to-face format (*n*=212, 74·4%), in a medical setting (*n*=163, 61·7%), with 130 (44·8%) of studies using >one method of delivering care and 34 (11·7%) using >one setting for delivery. Program reach was reported by 120

Table 2.
Summary implementation characteristics of included studies.

	Category	Sub-category	n(%) of studies
EPOC Delivery arrangement n(%)*	How and when care delivered	Group vs individual care	10 (3·4)
	Where care is provided	Outreach services	11 (3·9)
		Site of service delivery	23 (7·9)
	Who provides care	Role expansion or task shifting	21 (7·6)
		Self-management	48 (16·6)
	Coordination of care	Care pathways	17 (5·9)
		Case management	2 (0·7)
		Communication between providers	20 (6·2)
		Disease management	27 (9·3)
		Integration	1 (0·3)
		Packages of care	110 (37·9)
		Teams	4 (1·4)
	Information and communication technology	Health information systems	5 (1·7)
		The use of information and communication technology	10 (3·4)
		Telemedicine	1 (0·3)
EPOC implementation strategy *n*(%)*	Targeted at healthcare workers	Audit and feedback	8 (2·8)
		Educational materials	15 (5·2)
		Educational meetings	8 (2·8)
		Educational outreach visits, or academic detailing	5 (1·7)
		Clinical Practice Guidelines	5 (1·7)
		Inter-professional education	4 (1·4)
		Local consensus processes	14 (4·8)
		Local opinion leaders	1 (0·3)
		Patient-mediated interventions	46 (15·9)
		Reminders	23 (8·0)
		Tailored interventions	1 (0·3)
	Targeted at specific types of practice, conditions or settings	Health conditions	198 (68·5)
Delivery characteristics *n*(%)	Contact method (*n*=285)	Face to face	212 (74·4)
		Written	37 (13)
		Telephone	16 (5·6)
		Electronic	15 (5·3)
		Other	5 (1·8)
	Frequency of contact (*n*=227)	Once	78 (34·4)
		More than once but less than 3 monthly	42 (18·5)
		2-3 monthly	11 (4·8)
		< weekly to monthly	8 (3·5)
		Weekly	82 (36·1)
		daily	6 (2·6)
	Contact location (*n*=264)	Medical practice / hospital	163 (61·7)
		University / research facility	12 (4·5)
		Community facility	30 (11·4)
		Home	59 (22·3)
	Group vs individual care (*n*=260)	Individual	195 (75)
		Group	29 (11·2)
		Both	36 (13·8)
Implementation summary statistics	Reach (*n*=12), mean (SD)		62,8% (23)
	Fidelity (*n*=77), mean (SD)		75% (19.2)
	Drop-out (n=155), median (IQR)		15.4% (8.2, 27)

Footnote: EPOC: Effective practice and organisation of care; *n>289 and percentages add to >100% as studies may have more than one classification.

(41·4%) studies, fidelity by 77 (26·6%) studies, and loss to follow-up was reported by 155 (53.6%) studies (Table 2). Frequency of care contact varied between models and within the same model (Table S1). Of primary exercise studies, 62 studies included at least weekly (48 ≥3 times weekly) contacts, and five were daily. Exercise duration was reported for 64 studies, with a mean (SD) of 53·9 (24·1) min. Education study contact frequency varied with 34 once only, 13 more than once but less than three-monthly, six less than weekly up to monthly, 18 weekly and one daily. The duration of each education session was reported for 30 studies, with a median (IQR) of 52·5 (26·3, 60) min.

3.5. Study outcomes (Table S1)

Overall, 156 (52·2%) of studies reported a significant improvement in one or more of their outcomes (Table S1). The most common outcomes reported were specific osteoporosis treatment rates (antiresorptive / anabolic agents, *n*=113, 39·1%), followed by DXA rates (*n*=87, 30·1%). Provider outcomes, including prescribing and investigation ordering, were assessed in only 58 (20·1%) studies, of which 18/48 (37·5%) studies reported a significant increase in prescribing rates. Of the MoC reporting treatment rates, the majority used the EPOC delivery arrangement 'coordination of care' (*n*=80, 70·8%), followed by 'who provides care' (*n*=30, 26·5 %), with the most common subcategory being 'packages of care' (*n*=47, 41·6%) (Table S1). The most common implementation strategy was 'targeted at healthcare workers' (*n*=59, 52·2%), followed by 'targeted at a disease' (*n*=57, 50·4%). Only 38 (33·6%) studies found a significant increase in rates of treatment, including 30 studies classified as 'coordination of care', and using the implementation strategy of 'targeting a disease' in 20 and 'targeting healthcare workers' in 19. Of the MoC reporting DXA rates, most were classified as 'coordination of care' (*n*=63, 72·4%), followed by 'who provides care' (*n*=25, 28·7%), with the most common subcategory of 'packages of care' (*n*=40, 46%). The most common implementation strategy was 'targeted at a specific disease' (*n*=49, 56·3%), followed by 'targeted at healthcare workers' (*n*=41, 47·1%).

Most studies [45 (51·7%)] found a significant increase in DXA completion rates, including 30 studies classified as 'coordination of care', and using the implementation strategy of 'targeting healthcare workers' in 25 and 'targeting a disease' in 21 (Table S1).

3.6. Fracture outcomes (Tables 3, S2, S4)

Fracture outcomes were reported for 66 (22·8%) MoC, for 31 (47·7%) of these fracture was the primary outcome (Tables 3 and S2). Risk of bias assessment was performed for 43 studies (controlled trials, cohort studies and controlled before and after studies), with only 17 (38·6%) graded as high quality.

47 (72·3%) studies had a comparator group for fracture outcomes, of these, 19 (40·4%) found a significant reduction in fractures (Tables 3 and S4). The majority of studies that found a significant fracture reduction had this as a primary outcome (*n*=16, 84·2%), however only four (21·1%) studies were graded as high quality. Studies that found a significant fracture reduction had median (IQR) follow-up duration of 24 (15, 36·9) months, median (IQR) patient number of 403 (157, 1830), median (IQR) reach of 41·5% (25·5, 61·4) and median (IQR) loss to follow-up of 27·8% (15·8, 30·7). Of the 28 studies which did not find a significant reduction in fractures, 13 (46·4%) were graded as high quality. These studies had a shorter median (IQR) follow-up duration of 12 (12, 25·8) months, median (IQR) patient number of 724 (305, 4326), median (IQR) reach of 67·7% (40·4, 78·3) and median (IQR) loss to follow-up of 14·4% (5·4, 25).

3.7. BMD outcomes

73 (25·3%) MoC reported BMD outcomes, for 66 (90·4 %) of these BMD was the primary outcome (Tables 4 and S3). The majority of these were exercise MoC (*n*=65, 89·0%). 41 (56·2%) studies found a significant improvement in BMD with the MoC. This significant improvement in BMD was seen at the lumbar spine in 27 studies, femoral neck in 18 studies and total hip in 17 studies. 21 studies found an improvement in BMD at >one region of interest.

Studies that found a significant improvement in BMD had median (IQR) follow-up duration of 12 (6, 18) months, median (IQR) patient number of 70 (39, 140), median (IQR) reach of 80·7% (52·6, 89·1) and median (IQR) loss to follow-up of 13·7% (6·2, 22·1). The setting for delivering care was mostly in the community (*n*=10, 24·4%), medical centre (*n*=8, 19·5%) or research facility (*n*=7, 17·1%). Studies that did not find a significant improvement in BMD had median (IQR) follow-up duration of 12 (5·9, 12) months, median (IQR) patient number of 84 (41, 146), median (IQR) reach of 55·8% (50·4, 70·3) and median (IQR) loss to follow-up of 13% (9·1, 26·2). The setting for delivering care for these studies was mostly in the community (*n*=12, 37·5%) or home (*n*=9, 28·1%).

3.8. Gaps in reporting

Only 20 (6·9%) studies reported on consumer satisfaction, seven (2·4%) reported on clinician satisfaction, and 17 (5·9%) reported on cost. Adverse outcomes were reported by 37 (12.8%) of studies and 29 of these were exercise studies. Of these, 17 studies reported musculoskeletal adverse effects, and 16 reported no adverse effects.

4. Discussion

To our knowledge, this is the largest comprehensive review of both primary and secondary MoC for osteoporosis. The most common MoC for osteoporosis were classified as 'coordination of care', with the subcategory of 'packages of care', and used the implementation strategy of 'targeting a specific disease'. The most common activities are FLS and education. Few studies report on implementation characteristics of the model, such as reach, fidelity, and loss to follow-up, which may limit the ability for the MoC to be adapted to other settings and affect the rigour of the results. The majority of models showed an improvement in their primary outcome, although within each outcome, there were mixed results for similar types of models.

It is critical to recognise that implementation characteristics of MoC can influence outcomes [32]. Yet no previous reviews have assessed delivery and implementation characteristics of MoC for osteoporosis, and studies often omit these key details from publications. For example, a FLS may involve face-to-face, telephone or written contact, and may occur on the hospital ward, in a designated clinic or remotely, and each of these approaches may lead to different results. Furthermore, the ability of staff to screen all eligible patients, uptake of FLS by invited patients, fidelity to standardised investigations, and dropout rates, will influence the efficacy of the program. Less than half of included studies reported the reach of the MoC or fidelity to the program, and only half reported loss to follow-up. Where studies have high dropout rates or low reach or fidelity, consumer and clinician feedback may help to explain reasons for this, including the acceptability of the MoC, burden or perceived lack of efficacy, however this was rarely reported by studies. Co-design is now considered standard practice for developing MoC, and consumer and clinician perspectives should be included routinely when reporting MoC [33,34].

We are not the first group to attempt to summarise clinical outcomes of MoC for osteoporosis. Three recent systematic reviews analysed DXA and treatment rates among adults at risk of, or with prior, fragility fracture [15,16,35]. Two included only randomised controlled trials, while one also included quasi-experimental studies with a control group. All used different classification systems for MoC, with one classifying by activities (such as screening, education, feedback) [15], one broadly grouping MoC (FLS, case management, orthopaedic / fracture clinic) [16], and one classifying as structural, healthcare provider- or patient-focussed [35]. Results were mixed. While one study found a significant increase in treatment and DXA rates in a pooled analysis of all types of models [15], another found this benefit for structural and patient-focussed interventions [35], and another only found evidence for benefit in the population who had a prior fracture [16]. In a sub-analysis of studies including only people without prior fracture, the only intervention with benefit was self-scheduling of DXA with education, which increased DXA rates [16]. Several previous reviews have also focussed only on secondary prevention after a fracture [17–19]. One review included only RCTs, while others included additional study types. Again, different classification systems were used to group MoC, with one study not grouping models at all, one classifying models of care as FLS Types A-D, and the other classifying models based on the presence or absence of dedicated personnel, whether BMD was ordered or treatment initiated within model, and whether the model was "intensive" (both of the former criteria) [17–19]. These reviews suggested improvement in treatment rates overall, with a trend towards increased efficacy for more intensive MoC, while results for increased DXA rates were mixed. These mixed results between reviews may relate to inclusion criteria, differences in classifying models of care or implementation characteristics not reported in these reviews. We have attempted to use a validated system for classifying models of care, that can be replicated by other studies, and to include detail on implementation characteristics which may explain differences between trial results.

Although treatment rates are an important outcome for MoC for osteoporosis, it is important to understand that not all patients in primary prevention studies require treatment. The proportion who require treatment will depend on the population and risk of re-fracture, and the success of this treatment depends on patient adherence [36]. Fracture outcomes have been included in two previous reviews, one focussed on secondary prevention after fracture, and the other including both primary and secondary prevention [15,17]. One study including only RCTs performed a meta-analysis of 10 studies, which

Table 3.
Summary of studies reporting significant reduction in fractures.

Author (year)	Study design	Type of MoC	Population and sample size (*n*)	Follow-up months	Delivery of MoC				EPOC taxonomy		Clinical outcomes		Program reach and loss to follow-up	Risk of Bias
					Frequency of contact	Contact method	Contact location	Group vs individual care	Delivery arrangement	Implementation strategy	Primary outcome?	Fracture outcomes		
FLS														
Amphansap (2016)[37] Thailand	Cohort study	FLS type A	>50 yr inpatient with MTF 75	12	More than once, but less than 3monthly	Face to face	Hospital *Home*	Individual	Packages of care	Targeted at specific health conditions	Fracture	**0 (0%) MTF vs 36 (30%) in prior cohort, $p<0.001$**	Reach: not reported Loss to follow-up: intervention 15·7%; control not reported	+
Bachour (2017)[38] Lebanon	Cohort study	FLS type A	>50 yr ED patient with MTF 250	24	Not reported	Face to face	Hospital	Individual	Packages of care	Targeted at specific health conditions	Fracture	**8 (8·2%) total fractures vs 18 (18%) in prior cohort, $p=0.004$**	Reach: not reported Loss to follow-up: Intervention 81·7%; Control 23·1%	+
Davidson (2017) [39] Australia	Cohort study	FLS type C	>45 yr inpatient with MTF 140	36	Once	Not reported	Not reported	Individual	Communication between providers	Educational materials; Patient-mediated interventions	Investigation and treatment	**34 (10·5%) MTF vs 25 (19·1) in prior cohort, $p<0.05$ 13 (8·3%) hip fractures vs 16 (23·2%) in prior cohort, $p<0.01$**	Not reported	+
Huntjens (2011) [40] Netherlands	Cohort study	FLS type A	≥50 yr outpatient or ED patient with non-VF 3255	26	More than once, but less than 3monthly	Face to face	Hospital	Individual	Packages of care	Targeted at specific health conditions	Fracture	**89 (6·7%) total fractures vs 191 (9·9%) in prior cohort, $p=0.001$**	Reach: 68·4% Loss to follow-up: not reported	+
Inderjeeth (2018) [41] Australia	Cohort study	FLS type A	≥50 yr ED patient with MTF 339	12	Not reported	Face to face	Hospital *Home*	Individual	Packages of care	Targeted at specific health conditions	Fracture	MTF 17 (8·1%) vs 17 (18·3%) in prior cohort and 8 (17·3%) in usual care, **$p<0.05$ vs prior cohort only**	Reach: 64·1% Loss to follow-up: Intervention 16·2%; Usual care 18·2%; Prior cohort 12·4%	++
Lih (2011)[42]	Cohort study	FLS type A	≥45 yr outpatient with non-VF 403	48	More than once, but less than 3monthly	Face to face	Hospital	Individual	Packages of care	Targeted at specific health conditions	Fracture	**10 (4·1%) MTF vs 31 (19·7%) in usual care, $p<0.01$** 1 (0·4%) hip fracture vs 8 (5·1%) in usual care	Reach: 41·5% Loss to follow-up: Intervention 14·6%; Usual care 36·2%	0
Nakayama (2016) [43] Australia	Cohort study	FLS type A	≥50 yr ED patient with MTF 931	36	Not reported	Face to face	Hospital	Individual	Packages of care	Targeted at specific health conditions	Fracture	**63 (12·2%) total fractures vs 70 (16·8%) in usual care, $p=0.025$**	Reach: 20% Loss to follow-up: not reported	+
Van der Kallen (2014)[44] Australia	Cohort study	FLS type A	≥50 yr ED patient with MTF 434	12	More than once, but less than 3monthly	Face to face *Telephone*	Hospital *Home*	Individual	Packages of care	Targeted at specific health conditions	Fracture	**11 (6·5%) total fractures vs 36 (18·6%) in usual care, $p<0.001$** 3 (1·4%) VF vs 4 (1·8%) in usual care	Reach 14% Loss to follow-up: Intervention 27·2%; Usual care 45·5%	+
Wasfie (2019)[45] United States	Cohort study	FLS type A	≥50yr outpatient with VF treated surgically 365	26	2-3 monthly	Face to face	Hospital	Individual	Packages of care	Targeted at specific health conditions	Fracture	**78 (37%) total fractures vs 84 (56%) in prior cohort, $p=0.01$** 46 (22%) VF vs 47 (31%) in prior cohort, $p=0.29$	Not reported	0
Education														
Becker (2011)[46], Heinrich (2013) [47] Germany	Controlled before after	Education – patient & clinician *Exercise*	≥65yr in nursing home Clinicians: not reported Patients: 45321	12	Education: not reported Exercise: 60min 2x per wk for 52wk	Face to face *Written Video*	Home	Group	Disease management	Local opinion leaders	Fracture	**331 (2·4%) hip fractures vs 917 (2·9%) in usual care, $p<0.05$**	Not reported	+
Pekkarinen (2013) [48] Finland	Non-randomised study	Education – patient	60–70 yr post-menopausal women 2178	120	150min 5x per wk for 1 wk	Face to face *Written*	Medical Centre	Both	Self-management	Targeted at specific health conditions	Fracture	**59 (5·9%) MTF vs 95 (8·1%) in usual care, $p=0.045$ 12 (1·2%) hip**	Reach: 39·4% Loss to follow-up: Intervention 28·7%; Control 37·6%	-

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Table 3. (*Continued*)

Author (year)	Study design	Type of MoC	Population and sample size (*n*)	Follow-up months	Delivery of MoC				EPOC taxonomy		Clinical outcomes		Program reach and loss to follow-up	Risk of Bias
					Frequency of contact	Contact method	Contact location	Group vs individual care	Delivery arrangement	Implementation strategy	Primary outcome?	Fracture outcomes		
												fractures vs 29 (2·5%) in usual care, *p*=0·039		
Sorbi (2016)[49] Iran	Cohort study	Education - clinician	Orthopedic surgeons ≥60 yr inpatient with MTF Clinicians: 30 Patients: 515	24	15min 2x per wk for 13 wk	Face to face	Hospital	Group	Disease management	Educational materials	Treatment	**0·8 total fractures per person per year vs 1·6 in previous cohort, *p*<0·05**	Not reported	0
Screening														
Harness (2012) [50] United States	Cohort study	Screening – DXA	≥65 yr female, ≥70 yr male, or ≥50 yr at risk of OP 524612	72	Not reported	Face to face *Written*	GP practice	Individual	Disease management	Targeted at specific health conditions	Fracture	**2595 (1·5%) DR fractures vs 6063 (1·7%) in usual care, *p*<0·05**	Not reported	+
Parsons (2019) [51], Shepstone (2018)[12] United Kingdom	RCT	Screening – DXA, FRAX	70–85 yr women 12483	60	Once	Written	GP practice	Individual	Disease management	Targeted at specific health conditions	Fracture	951 (15·3%) total fractures vs 1002 (16%) in usual care, *p*=0·183 805 (12·9%) MTF vs 852 (13·6%) in usual care, *p*=0·178 **164 (2·6%) hip fractures vs 218 (3·5%) in usual care, p =0·002**	Reach: 95·6% Loss to follow-up: Intervention 14·4%; Control 14·8%	++
Zhumk-hawala (2013)[52] United States	Cohort	Screening – DXA	≥50 yr males w prostate cancer on leuprolide 1482	36	Once	Face to face *Written*	GP practice	Individual	Disease management	Patient-mediated interventions Reminders	Fracture	**18 (1·68%) hip fractures vs 17 (4·14%) in usual care, *p*<0·001**	Not reported	+
Exercise														
Kemmler (2012, 2014, 2015, 2016, 2016,2017)[53-58] Germany	Controlled before and after study	Exercise	Post-menopausal women with osteopenia 137	192	40min 4x per wk for 800 wk	Face to face *Written*	Home *Other not reported*	Both	Self-management	Targeted at specific health conditions	Fracture	**17 (28·8%) total fractures vs 28 (60·9%) in usual care, *p*=0·03** **13 (22%) MTF vs 24 (52·2%) in usual care, *p*=0·046**	Reach: 53·3% Loss to follow-up: Intervention 31·4%; Control 10·9%	++
Korpe-lainen (2010)[59] Finland	RCT	Exercise	70–73 yr women with low BMD 160	85 (fractures) 72 (BMD)	25min daily	Face to face	Home *Other not specified*	Both	Group vs individual care	Targeted at specific health conditions	BMD	17 (20·2%) total fractures vs 23 (30·3%) in usual care, *p*=0·22 **0 hip fractures vs 5 (6·6%) in usual care, *p*=0·02** 1 (1·2%) VF vs 1 (1·3%) in usual care	Reach: 25·5% Loss to follow-up: Intervention 34·5%; Control 40·8%	++
OGS														
Cheung (2018) [60] Hong Kong	Cohort	OGS *Specialist review Education – patient Exercise Patient support*	≥65 yr w hip fracture 153	18	Exercise: 60min weekly Vibration: 20min 3x per wk Education 3-monthly	Face to face	Community *Hospital*	Both	Disease management	Targeted at specific health conditions	Fracture	**1 (1·3%) total fractures vs 8 (10·4%) in usual care, *p*=0·034**	Reach: not reported Loss to follow-up: Intervention 28·3%; Control 25·2%	+
Specialist review														
Gomez (2019)[61] Australia	Pre-test post-test study	Specialist review	≥65 yr referred to falls and fracture clinic 106	6	Once	Face to face	Hospital	Individual	Disease management	Targeted at specific health condition	Fractures	**8·6% total fractures, *p*<0·001 vs baseline**	Reach: not reported Loss to follow-up: 10·9%	n/a

Footnote: p values are between groups unless otherwise specified. Risk of bias: ++ (high quality), + (acceptable), - (low quality), 0 (unacceptable). MoC: model of care; EPOC: effective practice and organisation of care; FLS: fracture liaison service; yr: year; MTF: minimal trauma fracture; ED: emergency department; VF: vertebral fracture; min: minutes; wk: week; DXA: dual energy X-ray absorptiometry; OP: osteoporosis; GP: general practitioner; DR: distal radius; RCT: randomised controlled trial; BMD: bone mineral density; OGS: orthogeriatric service.

Table 4.
Summary of studies reporting significant improvement in BMD.

Author (year)	Study design	Type of MoC	Population and sample size (*n*)	Follow-up months	Delivery of MoC				EPOC taxonomy		Clinical outcomes		Program reach and loss to follow-up
					Frequency of contact	Contact method	Contact location	Group vs individual care	Delivery arrangement	Implementation strategy	Primary outcome?	BMD change	
FLS													
Chandran (2013)[62] Singapore	Case study	FLS type A	≥50 yr inpatient, outpatient or ED patient with MTF 287	24	More than once, but less than 3monthly	Face to face *Telephone*	Hospital *Home*	Individual	Packages of care	Targeted at specific health conditions	Treatment	**LS: +4·4%, $p<0·01$ vs baseline TH +2·7%, $p<0·01$ vs baseline**	Not reported
Eekman (2014)[63] Netherlands	Case study	FLS type A	≥50 yr ED patient with MTF 1116	12	2-3 monthly	Face to face *Telephone*	Hospital *Home*	Individual	Packages of care	Targeted at specific health conditions	Reasons for not attending FLS and adherence	**LS: +3·9%, $p<0·001$ vs baseline TH: +2·3%, $p<0·001$ vs baseline**	Reach: 50·6% Loss to follow-up: 74·9%
Education													
Hien (2009)[64] Vietnam	Non-randomised trial	Education – patient	Postmenopausal women with low calcium intake 140	18	Daily	Face to face *Written Video*	Home *Community*	Both	Packages of care	Targeted at specific health condition	Calcium intake	**Calcaneal*: 0%; control -0·5%, $p<0·05$** *calcaneal US	Reach not reported Loss to follow-up: Intervention 18·6%; Control 31·7%
Wang (2016)[65] China	RCT	Education – patient *Exercise Patient support*	Known OP 436	48	Monthly	Face to face Written	Community	Both	Packages of care	Targeted at specific health condition	Multiple outcomes including BMD	**Females: LS: +10·4% vs control +2·19%, $p<0·01$ FN: +14·1% vs control +2·7%, $p<0·01$ Males: LS: +10·5% vs control +1·06%, $p<0·01$ FN: +11·1% vs control +1·14%, $p<0·01$**	Reach: not reported Loss to follow-up: Intervention 6·4%; Control 13·8%
Exercise													
Aboarrage (2018)[66] Brazil	RCT	Exercise	Postmenopausal women 25	6	30 min 3x per wk for 24 wk	Not reported	Community	Not reported	Site of service delivery	Targeted at specific health condition	BMD	**LS +3·7% vs control +0·88%, $p<0·01$ TF +6·5% vs control -1·38%, $p<0·01$**	Reach: not reported Loss to follow-up: 0%
Alayat (2018)[67] Saudi Arabia	RCT	Exercise *Laser* Group 1 laser Group 2 exercise Group 3 laser & exercise	Men with low BMD 100	12	20 min exercise ± 18min laser 3x per wk for 24 wk	Face to face	Not reported	Not reported	Packages of care	Targeted at specific health condition	BMD	**LS: Group 1 -1%, Group 2 +10·1%, Group 3 +13% vs control -1·5%, $p<0·001$ Group 3 vs control TH: Group 1 0%; Group 2 +3·3%; Group 3 +2·2% vs control-1·1%, $p<0·001$ Group 3 vs control or Group 1**	Reach: not reported Loss to follow-up: Group 1 16%; Group 2 12%; Group 3 12%; Control 20%
Almstedt (2016)[68] United States	Pre-test post-test	Exercise	Female cancer survivors 26	7	60 min 3x per wk for 26 wk	Face to face	University	Not reported	Packages of care	Targeted at specific health condition	BMD	**LS +2·5% vs baseline, $p=0·012$ TH +1·7% vs baseline, $p=0·048$**	Reach: not reported Loss to follow-up: 23·1%
Angin (2015)[69] Turkey	RCT	Exercise	Post-menopausal women with low BMD 44	6	60 min 3x per wk for 24 wk	Face to face	Not reported	Group	Group vs individual care	Targeted at specific health condition	BMD	**LS +6·5% vs control-3·3%, $p<0·001$**	Reach: not reported Loss to follow-up: not reported
Astorino (2013)[70] United States	Pre-test post-test	Exercise	Spinal cord injury 13	6	150 min 2x per wk for 26 wk	Face to face	Rehab centre	Individual	Packages of care	Targeted at specific health condition	BMD	**LS: +4·7% vs baseline, $p<0·05$ TH: -7% vs baseline, $p<0·05$ FN -4% vs baseline, $p<0·05$**	Reach: not reported Loss to follow-up: 23·1%

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Table 4. (*Continued*)

Author (year)	Study design	Type of MoC	Population and sample size (*n*)	Follow-up months	Delivery of MoC				EPOC taxonomy		Clinical outcomes		Program reach and loss to follow-up
					Frequency of contact	Contact method	Contact location	Group vs individual care	Delivery arrangement	Implementation strategy	Primary outcome?	BMD change	
Basat (2013)[71] Turkey	RCT	Exercise Group 1 strength exercise Group 2 high-impact exercise	Postmenopausal women with low BMD 42	6	60 min 3x per wk for 26 wk	Face to face	Hospital	Not reported	Packages of care	Targeted at specific health condition	BMD	**LS: Group 1 +1·3%; Group 2 +0·5% vs control-2·5%, *p*=·006 Group 2 vs control FN: Group 1 +1·6%; Group 2 1·2% vs control -1%, *p*=0·006 Group 2 vs control**	Reach: not reported Loss to follow-up: Group 1 21·4%; Group 2 14·3%; Control 14·3%
Beavers (2014)[72] United States	RCT	Exercise *Education – patient* Group 1: Diet plan Group 2: Exercise Group 3: Diet plan & exercise	≥55 yr, BMI 27-40 and osteoarthritis of knees 392	18	Exercise: 60 min 3x per wk Education: 1-2 weekly	Face to face	Community Home	Both	Packages of care	Targeted at specific health condition	BMD	LS: Group 1 +0·3%; Group 2 +0·5% vs Group 3 -0·1%; *p*=0·47 **TH: Group 1 -2·5%; Group 2 -0·2% vs Group 3 -2%, *p*<0·01 Group 1 vs Group 3 FN: Group 1 -1·9%; Group 2 -0·3% vs Group 3 -1·8%, *p*<0·01 Group 1 vs Group 3**	Reach: 86·3% Loss to follow-up: Group 1 31%; Group 2 26·4%; Group 3 25%
Bergstrom (2012)[73] Sweden	RCT	Exercise	Postmenopausal women with low BMD and DR fracture 112	12	40 min 3-4x wk for 52 wk	Face to face	Community	Not reported	Site of service delivery	Targeted at specific health condition	BMD	**TH: +0·7% vs control -0·9%, *p*=0·04**	Reach: not reported Loss to follow-up: Intervention 20%; Control 15·4%
Bocalini (2009)[74] Brazil	RCT	Exercise	Postmenopausal women 35	6	60 min weekly for 24 wk	Face to face	Community	Not reported	Site of service delivery	Targeted at specific health condition	BMD	**LS: -0·1% vs control -1%, *p*<0·05 FN: -0·14% vs control -1·6%, *p*<0·05**	Reach: not reported Loss to follow-up: Intervention 13%; Control, 16·7%
Bolton (2012)[75] Australia	RCT	Exercise	Postmenopausal women with low BMD 39	12	60 min 3x per wk for 52 wk	Face to face	Community	Not reported	Site of service delivery	Targeted at specific health condition	BMD	LS: -0·3% vs control -0·9% $p>0·05$ **TH: +0·5% vs control -0·9%, *p*=0·02**	Reach :34·5% Loss to follow-up: Intervention 0%; Control 10%
Borba-Pinheiro (2016) [76] Brazil	RCT	Exercise Group 1: 3x per wk Group 2: 2x per wk	Postmenopausal women with low BMD 60	13	60 min for 56wk	Face to face	Not reported	Not reported	Packages of care	Targeted at specific health condition	BMD	Absolute change not reported. **$p<0·05$ Group 1 vs control for TH, FN** $p<0·05$ Group 1 vs Group 2 for LS, TH and FN	Reach: 96·8% Loss to follow-up: Group 1 0%; Group 2 20%; Control 20%
Chuin (2009)[77] Canada	RCT	Exercise *Antioxidants* Group 1: antioxidants Group 2: exercise Group 3: Antioxidants & exercise	Postmenopausal women 34	6	Exercise: 60 min 3x per wk for 26 wk	Face to face	Not reported	Not reported	Packages of care	Targeted at specific health condition	BMD	**LS: Group 1 0·1%; group 2 -0·1%; Group 3 -0·3% vs control -1·5%, *p*<0·05 all groups vs control** FN: Group 1 +0·9%; Group 2 -0·3%; Group 3-1·4% vs control +0·2%, $p>0·05$	Reach: not reported Loss to follow-up: not reported
	RCT	Exercise *Education –*	≥60 yr	18	60 min 3x per wk for 78 wk	Face to face *Telephone*	Community	Both	Packages of care	Targeted at specific health conditions	BMD	LS: +1·49% vs control +0·76%, *p*=0·125	Reach: not specified

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Table 4. (*Continued*)

Author (year)	Study design	Type of MoC	Population and sample size (*n*)	Follow-up months	Delivery of MoC				EPOC taxonomy		Clinical outcomes		Program reach and loss to follow-up
					Frequency of contact	Contact method	Contact location	Group vs individual care	Delivery arrangement	Implementation strategy	Primary outcome?	BMD change	
Daly (2019)[78], Gianoudis (2014)[79] Australia		*patient & clinician Patient support*	Clinicians: not reported Patients: 162			*Written*						TH: +0·61% vs control +0·32%, $p>0·05$ **FN: +0·6% vs control -1·33%, $p<0·001$**	Loss to follow-up: Intervention 4·9%; Control 12·3%
deMatos (2009)[80] Portugal	Non-randomised trial	Exercise	Postmenopausal women with low BMD 59	12	45 min, frequency not reported, for 52 wk	Not reported	Not reported	Not reported	Packages of care	Targeted at specific health condition	BMD	**LS +1·17% vs control -2·26% $p<0·013$** TH: -0·71%; control -0·6%, $p>0·05$	Reach: not reported Loss to follow-up: not reported
El-Kader (2016)[81] Saudi Arabia	RCT	Exercise	COPD on inhaled glucocorticoids 60	6	30 min 3x per wk for 26 wk	Not reported	Not reported	Not reported	Packages of care	Targeted at specific health condition	BMD	**LS: +20·8% vs control -1·1%, $p<0·04$ DR: +25·8% vs control -1·71%, $p<0·05$**	Reach: not reported Loss to follow-up: not reported
Elsisi (2015)[82] Egypt	RCT	Exercise Group 1: exercise Group 2: electromagnetic field	Postmenopausal women, sedentary 30	3	30 min (electromagnetic field) or 60min (exercise) 3x per wk for 12 wk	Face to face	Hospital	Not reported	Packages of care	Targeted at specific health condition	BMD	**LS: exercise 2·18% vs electromagnetic field +29%, $p<0·01$ FN: exercise +2·7% vs electromagnetic field +16·9%, $p=0·002$**	Reach: not reported Loss to follow-up: 0%
Garcia-Gomariz (2018)[83] Spain	RCT	Exercise	Postmenopausal women 36	24	60 min 2x per wk for 92 wk	Face to face	Hospital	Not reported	Packages of care	Targeted at specific health condition	BMD	LS: +24·3% vs control +14·7%, $p=0·4$ **FN: +36·8%; vs control -4·7% $p<0·05$**	Reach: not reported Loss to follow-up: Intervention 5·6%; Control 5·6%
Hojan (2013, 2013)[84]·[85]	Pre-test post-test	Exercise Phase 1 (control): no exercise Phase 2: aerobic exercise Phase 3: resistance exercise	Pre-menopausal women with breast cancer receiving endocrine therapy 41	18	45 min daily for 26 wk for each phase	Written *Face to face*	Home	Individual	Self-management	Targeted at specific health condition	BMD	6 month change,: **LS: Phase 2 -3·6%; Phase 3 +1·9% vs control -8·9%, $p<0·05$ phase 2 vs control, $p<0·01$ control vs baseline** TH: Phase 2 -1%; Phase 3 +1·1% vs control -6·8%, $p<0·01$ control vs baseline FN: Phase 2 -1·1%; Phase 3 -6·8%, p not reported Change from baseline: LS: -10·6% TH: -6·8%	Reach: not reported Loss to follow-up: 22·6%
Kemmler (2013)[86] Germany	RCT	Exercise	Postmenopausal women 85	12	60 min 3sx per wk for 52 wk	Face to face	Not reported	Group	Group vs individual care	Targeted at specific health condition	BMD	**LS: -0·1% vs control -2%, $p=0·002$** TH: -0·4% vs control -0·8%, $p=0·152$	Reach: 81% Loss to follow-up: Intervention 16·3%; Control 28·6%
Kemmler (2012, 2014, 2015, 2016, 2016,2017)[53-58] Germany	Controlled before and after study	Exercise	Post-menopausal women with osteopenia 137	192	40 min 4x per wk for 800 wk	Face to face *Written*	Home *Other not reported*	Both	Self-management	Targeted at specific health conditions	BMD	**LS: -1·5% vs control -5·8%, $p<0·001$ TH: -5·7% vs control -9·7% $p<0·01$ FN: -6·5% vs control -9·6%, $p=0·001$**	Reach: 53·3% Loss to follow-up: Intervention 31·4%; Control 10·9%
Kukuljan (2009, 2011)[87]·[88] Australia	RCT	Exercise *Fortified milk* Group 1:	Older males 180	18	60 min 3x per wk for78 wk	Face to face	Community	Group	Packages of care	Targeted at specific health condition	BMD	Absolute change not reported **LS: $p<0·01$, all**	Reach: 98·9% Loss to follow-up: Group 1

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Table 4. (*Continued*)

Author (year)	Study design	Type of MoC	Population and sample size (*n*)	Follow-up months	Delivery of MoC				EPOC taxonomy		Clinical outcomes		Program reach and loss to follow-up
					Frequency of contact	Contact method	Contact location	Group vs individual care	Delivery arrangement	Implementation strategy	Primary outcome?	BMD change	
		Exercise Group 2: Fortified milk Group 3: Exercise & fortified milk										**groups increased vs control** **FN: effect of exercise 1·9%, $p<0·001$**	2·2%; Group 2 2·2%; Group 3 2·2%; Control 4·5%
LeBlanc, (2013)[89], Sibonga (2019)[90] United States	Controlled before and after study	Exercise *Alendronate* Group 1: exercise Group 2: exercise & alendronate	Astronauts 35	12	150 min 6x per wk for 24 wk	Face to face	Home	Individual	Packages of care	Targeted at specific health condition	BMD	Absolute change not reported **$p<0·05$ Group 2 vs Group 1 at LS and TH**	Reach: not reported Loss to follow-up: Group 1 0%; Group 2 42·9%
Liu (2015)[91] China	RCT	Exercise Group 1: Tai Chi Group 2: Calcium & Vitamin D Group 3: Tai Chi, Calcium & Vitamin D	Postmenopausal women with low BMD 198	12	3 min daily for 52 wk	Not reported	Not reported	Not reported	Packages of care	Targeted at specific health condition	BMD	Absolute change not reported **LS: $p<0·05$ all groups improved vs control** **FN: Group 1 1·9% higher BMD than control, $p<0·001$; Group 3 2·3% higher BMD than control, $p<0·001$**	Reach: not reported Loss to follow-up: Group 1 4%; Group 2 10%; Group 3 2%; Control 12·5%
Marchese (2012)[92] Italy	RCT	Exercise	Women with low BMD 22	6	60 min 3x per wk for 24 wk	Face to face	Not reported	Group	Group vs individual care	Targeted at specific health condition	BMD	**LS: +14·9% vs control -6·6%, $p<0·001$** **TH: +5·06% vs control -8·6%, $p=0·026$** **FN: +10·39% vs control -4·63%, $p=0·002$**	Reach: not reported Loss to follow-up: not reported
Marques (2011)[93] Portugal	RCT	Exercise Group 1: resistance exercise Group 2: aerobic exercise	Postmenopausal women 71	8	60 min 3x per wk for 32 wk	Face to face	University campus	Group	Group vs individual care	Targeted at specific health condition	BMD	**TH: Group 1 +1·6%; Group 2 +0·12% vs control -0·84%, $p=0·034$ Group 1 vs other groups** FN: Group 1 -1·6%; Group 2 +0·46% vs control -0·29%, $p>0·05$	Reach: 86·6% Loss to follow-up: Group 1 34·8%; Group 2 20·8%; Control 16·7%
Morse (2019)[94] United States	RCT	Exercise *Zoledronic acid* Group 1: exercise & zoledronic acid Group 2: exercise	Non-ambulatory spinal cord injury 20	12	30 min 3x per wk for 52 wk	Face to face	Not reported	Not reported	Packages of care	Targeted at specific health condition	HRQCT	**Tibia CTI Group 1 +0·04% vs Group 2 -6·96%, $p=0·013$** **Tibia CBV: Group 1 +0·06% vs Group 2 -5·73%, $p<0·05$** **Distal femur CTI: Group 1 +0·25% vs Group 2 -1·02%, $p<0·05$** **Distal femur CBV: Group 1 +1·67% vs Group 2 +1·44%, $p<0·05$**	Reach: not reported Loss to follow-up: Group 1 70·6%; Group 2 71·4%
Murai (2019)[95] Brazil	RCT	Exercise	Bariatric surgery 70	6	75 min 3x per wk for 26 wk	Face to face	Hospital	Individual	Packages of care	Targeted at specific health condition	BMD	LS: -0·52% vs control -1·43%, $p>0·05$ **TH: -5% vs control -7·26%, $p=0·009$** **FN -4·41% vs control -7·33%, $p=0·007$**	Reach: 53·8% Loss to follow-up: Intervention 21·9%; Control 22·6%
Murtezani (2014)[96] Kosova	RCT	Exercise Group 1: land exercise Group 2:	Postmenopausal women with low BMD 64	10	35–55min 3x per wk for 43 wk	Face to face	Not reported	Not reported	Packages of care	Targeted at specific health condition	BMD	**LS: Group 1 +5·53% vs Group 2 +3·92%, $p<0·001$**	Reach: not reported Loss to follow-up: Group 1

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Table 4. (*Continued*)

Author (year)	Study design	Type of MoC	Population and sample size (*n*)	Follow-up months	Delivery of MoC				EPOC taxonomy		Clinical outcomes		Program reach and loss to follow-up
					Frequency of contact	Contact method	Contact location	Group vs individual care	Delivery arrangement	Implementation strategy	Primary outcome?	BMD change	
		aquatic exercise											6·1%; Group 2 3·2%
Nicholson (2015)[97] Australia	RCT	Exercise	Postmenopausal women 57	6	50 min 2x per wk for 26 wk	Face to face	Community	Group	Site of service delivery	Targeted at specific health condition	BMD	**LS: +1·01% vs control -2·09%, *p*=0·005 group x time** TH: -0·21% vs control -2·99%, $p>0·05$ FN: +0·11% vs control -1·5% $p>0·05$	Reach: 96·6% Loss to follow-up: Intervention 14·3%; Control 10·3%
Saarto (2012)[98] Finland	RCT	Exercise	Women with breast cancer 573	12	60 min 3x per wk for 52 wk	Face to face	Home	Both	Site of service delivery	Targeted at specific health condition	BMD	Premenopausal subgroup: LS: -1·9%; control -2·2%, $p>0·05$ **FN: -0·2%; control -1·4%, *p*=0·01** Postmenopausal subgroup: LS: -1·6%; control -2·1%, $p>0·05$ FN: -1·1%; control -1·1%, $p=0·99$	Reach: not reported Loss to follow-up: Intervention 7·3%; Control 6·3%
Sen (2020)[99] Turkey	RCT	Exercise *Vibration* Group 1: High impact exercise Group 2: Exercise & vibration	40–65 yr postmenopausal women with low BMD 49	6	60 min 3x per wk for 24 wk	Face to face	Research facility	Not reported	Packages of care	Targeted at specific health condition	BMD	**LS: Group 1 -0·7%; Group 2 +1·3% vs control -1·9%, *p*=0·005 Group 2 vs control FN: Group 1 +1·9%; Group 2 +5% vs control -2·9%, *p*=0·003 Group 2 vs control TH: Group 1 -0·6%; Group 2 +1·9% vs control -1·3%, *p*=0·031 Group 2 vs control**	Reach: Not reported Loss to follow-up: Group 1 15·8%; Group 2 21·1%; Control 10%
Silverman (2009)[100] United States	Non-randomised trial	Exercise	Postmenopausal women with BMI 25–40, sedentary 86	6	52 min 3x per wk for 26 wk	Face to face	Community Home	Individual	Packages of care	Targeted at specific health condition	BMD	LS: +0·42% vs control +0·18%, $p>0·05$ **FN: +1·86% vs control -0·87%, $p<0·05$**	Reach: not reported Loss to follow-up: not reported
Villareal (2017)[101] United States	RCT	Exercise *Specialist review* Group 1: diet & aerobic exercise Group 2: diet & resistance exercise Group 3: diet & combined exercise	≥65 yr, BMI >29, sedentary 160	6	Exercise: 60 min 4x per wk for 26 wk Dietician review: weekly	Face to face	University campus	Both	Packages of care	Targeted at specific health condition	Physical performance test. Secondary: BMD	LS: Group 1 +0·18%; Group 2 +0·7%; Group 3 +0·69% vs control +0·88%, $p>0·05$ **TH: Group 1 -2·6%; group 2 -0·57%; Group 3 -1·1% vs control +0·04%, $p<0·05$ Group 1 vs all other groups**	Reach: not reported Loss to follow-up: Group 1 12·5%; Group 2 12·5%; Group 3 12·5%; Control 10%
von Stengel (2011) [102] Germany	RCT	Exercise *Vibration* Group 1: exercise Group 2: exercise & vibration	Postmenopausal women 151	18	40 min 4x per wk for 78 wk	Face to face	University *Home*	Both	Packages of care	Targeted at specific health condition	BMD	**LS: Group 1 +2·05%; Group 2 +1·49% vs control +0·42%, $p<0·05$ Group 1 vs control** TH: Group 1 +0·12%; group 2 +0·12% vs control -0·12%, $p>0·05$	Reach: 80·3% Loss to follow-up: Group 1 10%; Group 2 14%; Control 7·8%
Watson (2015, 2018)[103]· [104] Australia	RCT	Exercise	Postmenopausal women 101	8	30 min 2x per wk for 35 wk	Face to face	University campus	Group	Group vs individual care	Targeted at specific health condition	BMD	**LS: +2·9% vs control -1·2%, $p<0·001$ FN: +0·1% vs control -1·8%, *p*=0·001**	Reach: 48·3% Loss to follow-up: Intervention 12·2%; Control 17·3%

(*continued on next page*)

Table 4. (*Continued*)

Author (year)	Study design	Type of MoC	Population and sample size (*n*)	Follow-up months	Delivery of MoC				EPOC taxonomy		Clinical outcomes		Program reach and loss to follow-up
					Frequency of contact	Contact method	Contact location	Group vs individual care	Delivery arrangement	Implementation strategy	Primary outcome?	BMD change	
Winters-Stone (2011) [105] United States	RCT	Exercise	≥50yr postmenopausal women with breast cancer 106	12	60 min 3x per wk for 52 wk	Face to face *Written*	University	Both	Group vs individual care	Targeted at specific health condition	BMD	**LS: +0·41% vs control -2·27%, p=0·013** TH: -0·35% vs control -0·83%, p>0·05 FN: -1·37% vs control -2·06%, p>0·05	Reach: not reported Loss to follow-up: Intervention 30·8%; Control 42·6%
Specialist Review Cheung (2013)[106] Australia	Pre-test post-test	Specialist review	Men with prostate cancer on ADT 113	24	2-3 monthly	Face to face	Hospital	Individual	Packages of care	Clinical practice guidelines	BMD	LS: -1·2% vs baseline, p=0·66 **TH: -2·1% vs baseline, p<0·001**	Reach: not reported Loss to follow-up: 26·1%

Footnote: p values are between groups unless otherwise specified. MoC: model of care; EPOC: effective practice and organisation of care; BMD: bone mineral density; FLS: fracture liaison service; yr: year; ED: emergency department; MTF: minimal trauma fracture; LS: lumbar spine; TH: total hip; US: ultrasound; RCT: randomised controlled trial; OP: osteoporosis; FN: femoral neck; min: minutes; wk: week; TF: total femur; BMI: body mass index; DR: distal radius; COPD: chronic obstructive pulmonary disease; HRQCT: high resolution quantitative computer tomography; CTI: cortical thickness index; CBV: cortical bone volume.

demonstrated no fracture reduction overall, or when analysed separately for models grouped by activity [15]. The other study included all study designs, but due to the small number of studies, lack of control group and lack of power, no statement could be made about the efficacy for fracture reduction [17]. It is important to note that we have reported fracture outcomes in any study reporting this, whether or not it was the primary outcome. We would like to highlight that many studies were not powered for fracture outcomes and did not include follow-up of sufficient duration to find a meaningful difference in fracture rates. Many studies also did not include a comparison group due to the study design. Of those that did compare fracture rates, less than half found a significant reduction in fractures, and few of these studies were graded as high quality. As a reduction in fractures is the most important outcome for any osteoporosis MoC, we hope that studies continue to follow up and report on fractures over time. More recently, BMD has been suggested as a surrogate marker for osteoporosis therapeutic trials. Few MoC other than exercise studies have reported this outcome, but it could be considered by investigators in the future.

There are several limitations to our study. The study is descriptive only and does not include comparative statistics due to the broad inclusion criteria in our search. In describing our primary clinical outcomes of fractures and BMD change, we included studies with these as both primary or secondary outcomes. Given this, studies may have been underpowered for these specific outcomes. Strengths of our study include summarising delivery and implementation characteristics of studies, and using the validated EPOC classification system to categorise MoC, which can be applied to a broad variety of different interventions, and reproduced in future studies. We have also included all types of study designs, reflecting the fact that RCTs are not always appropriate for reporting complex interventions, and making this review a comprehensive summary of MoC worldwide.

This comprehensive scoping review in a vital area of rising morbidity and mortality reveals a wide variety of MoC for people with or at risk of osteoporosis. A minority of studies reports delivery and implementation characteristics, and this may influence the efficacy of these models, and the ability to translate them to real-world practice. Results of the MoC demonstrate mixed efficacy for fracture reduction, increases in BMD, and other outcomes such as treatment and DXA rates, and these disparities may be explained by exploring implementation characteristics. We suggest that future studies should include implementation outcomes in their reports, consider a pragmatic trial or effectiveness implementation hybrid trial study design, and report on fractures, or BMD increases as a surrogate marker for this. Lastly, co-design, and the perspectives of clinicians and consumers, is vital to implementation. It is important that researchers recognise this and ensure that these perspectives are included in future studies.

Funding

None.

Data sharing statement

Data dictionary, data collection table, list of excluded studies provided on request to AJ, at alicia.jones@monash.edu.

Declaration of Competing Interest

AJ is supported by a National Health and Medical Research Council postgraduate research scholarship (Grant No. 1169192) and has received a travel grant from the Australian and New Zealand Bone and Mineral Society.

MH is supported by a National Health and Medical Research Council postgraduate research scholarship (Grant No. 2002671).

PE has received institutional grants or contracts from Amgen, the National Health and Medical Research Council, Alexion and Eli-Lilly; payments to institution from Amgen, is a participant on Celltrion Data Safety Monitoring Board or Advisory Board, and has a leadership or fiduciary role on the American Society for Bone and Mineral Research executive, International Osteoporosis Foundation board and Healthy Bones Australia board.

HT is the recipient of a National Health and Medical Research Council Fellowship Grant.

AV reports no conflicts of interest.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.eclinm.2021.101022.

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