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Review Article

Women's perceptions or experiences of physical activity and exercise interventions to improve bone health: a systematic review

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Abstract

Exercise is an important intervention to maintain bone health in women with osteopenia and osteoporosis. This systematic review aims to gain insight into the experiences or perceptions females have toward bone health interventions, to promote uptake and adherence. Four electronic databases were searched: MEDLINE, CINAHL, PubMed and PsycInfo. Inclusion Criteria: Qualitative studies examining perceptions or views of women to physical activity or exercise interventions aimed at improving bone health. 1,406 papers were identified. After screening, data were extracted from 2 studies considering experiences and 2 papers presenting perceptions of exercise for bone health. All studies scored >8 out of 10 on the CASP Quality Tool. Older women perceived barriers such as safety and advice, and facilitators of tangible results and feedback within supervised group sessions. Older womens' experiences of a digitally delivered exercise intervention included social interactions and voice reminders, with barriers of lack of feedback and knowledge. Younger women expressed enablers as feeling the benefits and physical literacy, and barriers of previous experience participating in tedious exercise. Supervised sessions, with different intensity levels and variety, offering feedback to promote confidence, are valuable to uptake and adherence in both younger and older females.

Keywords: Bone health, Exercise, Experiences, Perceptions, Physical activity

Introduction

Osteoporosis is a degenerative condition occurring when bone reabsorbed exceeds the amount of bone deposited, resulting in a net loss of bone density[1]. Lower bone density can lead to skeletal breaks and fractures resulting in pain, mobility issues and increased difficulties participating in the activities of daily living (ADL)[2]. It is estimated that over three million people within the United Kingdom (UK) are living with osteoporosis and hospitalizations due to fragility fractures costs the National Health Service over £4.4 billion a year[3]. Osteoporosis is more common in women and although osteoporosis is also found in men, research focusing on the male population is limited[4]. The frontline treatment for osteoporotic fractures is pharmaceuticals[7]. Oral bisphosphonates, along with calcium and vitamin D supplements, are the first choice of pharmaceuticals for osteoporosis as they help control the bone remodelling process and are of low cost[7]. Although medication successfully prevents fractures[5], exercise and physical activity (PA) can serve as a preventative measure, as the majority of fractures occur after a fall[6-8]. However, 'kinesphobia' or fear of movement due to the belief of susceptibility to injury, is common in people diagnosed with Osteoporosis[9]. Public health care needs to emphasize maintaining, as well as increasing, exercise and PA levels as a non-pharmaceutical treatment option to improve bone

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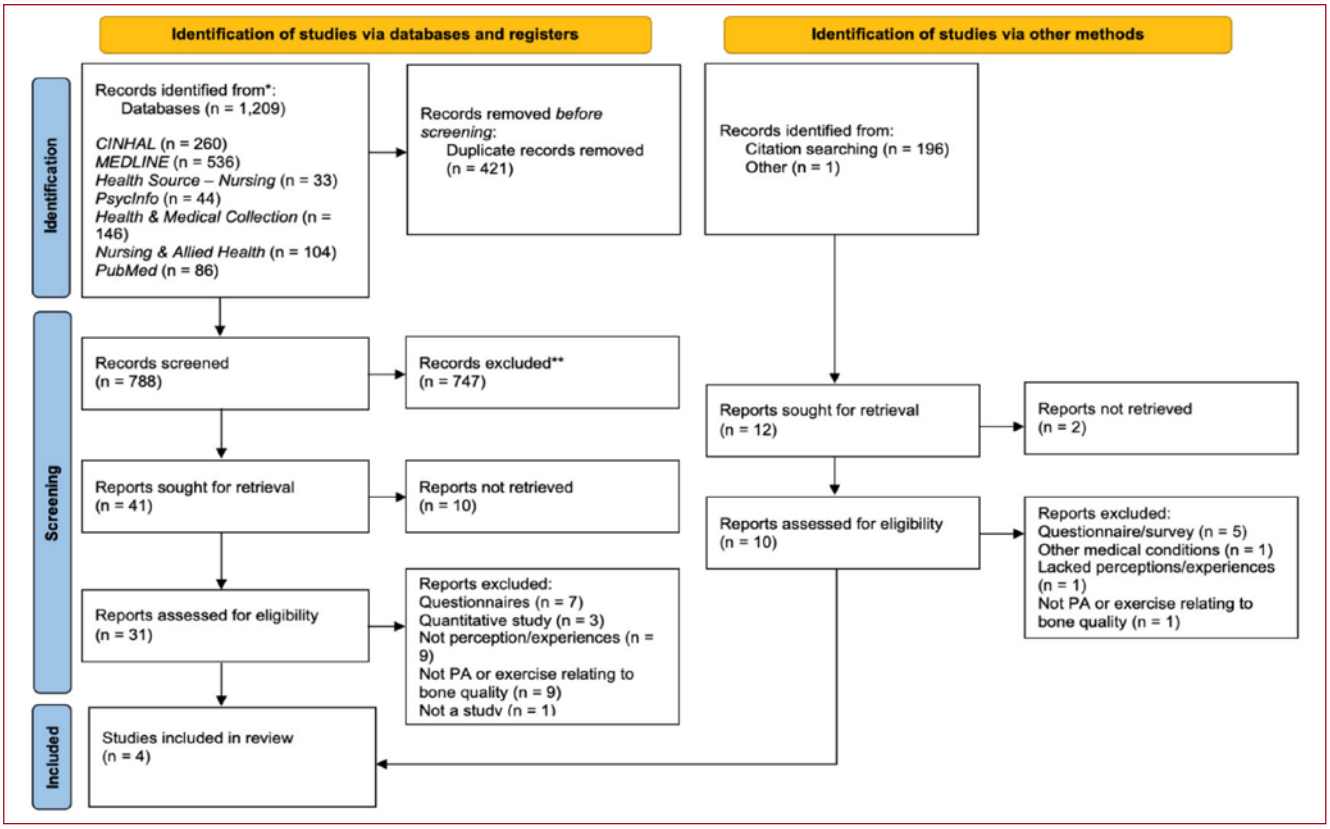

Figure 1. PRISMA diagram of the screening process. Key: * using search terms in text. ** excluded from title and abstract screening as not relevant.

health (bone density and bone quality), maintain quality of life and reduce the likelihood of falls.

Various studies and reviews have supported weight-bearing aerobic exercise and resistance training to bone health in individuals with osteoporosis and osteopenia[7-8,10-12]. Even high-intensity resistance and impact training (HIRIT) is a safe and effective treatment to improve bone health in individuals with osteoporosis[11]. Adherence to exercise for bone health suggests adherence rates between 52-100% but concluded that future work should identify barriers and facilitators to improve adherence[13]. Within studies considering exercise to prevent falls (as most fractures occur as a result of a fall) there is poor uptake (around 70%) and adherence (around 50%)[14]. Knowledge of individuals' perceptions and experiences of exercise to improve bone health may explain why adherence and uptake from participants is so poor. Therefore, this study aims to systematically review women's perceptions or experiences towards exercise and physical activity interventions to improve bone health in order to inform messaging to promote uptake and consider strategies to promote adherence.

Materials and Methods

This systematic qualitative review is based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[15].

Eligibility Criteria

Studies which explored, qualitatively, perceptions or experiences of physical activity or exercise which aimed to improve bone health in adult women. Studies were excluded if they did not seek views, if they considered an intervention where bone health was not the focus, if they were systematic reviews or protocols, not written in the english language or not retrievable as full papers.

Information Sources and Search

Four databases were searched on March 16th, 2022: PsycInfo, MEDLINE, CINAHL and PubMed. The search strategy included keywords pertaining to the population, exposure and outcome (PEO). Population: Female OR Women AND Adult. Exposure: Exercise, physical activity, exercise intervention or exercise program*. Outcome: perception,

Author, Date and Title	Aim	Study design	Method of data collection	Number of Participants	Age	Country	Intervention
Lambert et al. 2019[19], Enjoyment and Acceptability of Different Exercise Modalities to Improve Bone Health in Young Adult Women	Explore the experiences related to a bone-targeted exercise intervention, determine enjoyment and acceptability of each exercise mode, and identify barriers and facilitators to osteogenic exercise for young adult women	Mixed methods	semi-structured interviews	32	RT=20.5 yrs IT=23.2 yrs CON=34.9 yrs	Australia	10 month, 2x week, high intensity supervised resistance training (RT) OR Supervised high-intensity impact training (IT) OR "active" control group (CON).
Simmonds et al. 2016[21], An Exploration of Barriers and Facilitators to Older Adults' Participation in Higher Impact Physical Activity and Bone Health: A Qualitative Study	Explore the acceptability of doing high-impact physical activity in later life	Thematic analysis	Focus groups	31	65–75 yrs= 15 (48%) 75–88 yrs= 16 (52%)	United States of America	N/A
Baert et al. 2015[20], Motivators and Barriers for Physical Activity in Older Adults with Osteoporosis	The main objective of this qualitative study was to identify motivators for and barriers to PA specifically in older patients with osteoporosis	Methodological triangulation	Focus groups & semi-structured interviews	15	74 yrs (mean)	Belgium	N/A
Jansons et al. 2022[18], Barriers and Enablers for Older Adults Participation in a Home-based Pragmatic Exercise Program Delivered and Monitored by Amazon Alexa: A Qualitative Study	To explore the enablers and barriers for older adults aged 60 to 89 years participating in the home-based exercise program delivered by Alexa	Prospective, single arm pilot study	semi-structured interviews	15	70.3 yrs (mean)	Australia	12-week home-based exercise program from exercise physiologist via an Alexa device.

Table 1. Characteristics of the four included studies.

experience, view, interview, focus group OR qualitative. Adaptations to truncations and limiting factors were made based on the individual databases.

Search results were exported to RefWorks (ProQuest LLC RefWorks [software] 2022) and duplicates were removed. All titles and abstracts were independently screened by CRP and RW, and discrepancies were resolved by DAS. Papers included and the reference list of included studies were screened for eligibility to ensure no relevant studies were missed. Data (quotes and themes) were extracted into Microsoft Excel, version 2016 (Microsoft Corp, Redmond, WA) by CRP and 50% checked by RW. Data extracted included: authors, year, country, number of participants, aim, mean age, study design, intervention received and methods, themes and quotes.

Quality

The Critical Appraisal Skills Programme (CASP) quality appraisal tool was used to assess the methodological quality of the studies included in this systematic review[16,17]. The tool has ten questions that each focus on a different methodological aspect of a qualitative study[16]. One author (CRP) assessed the

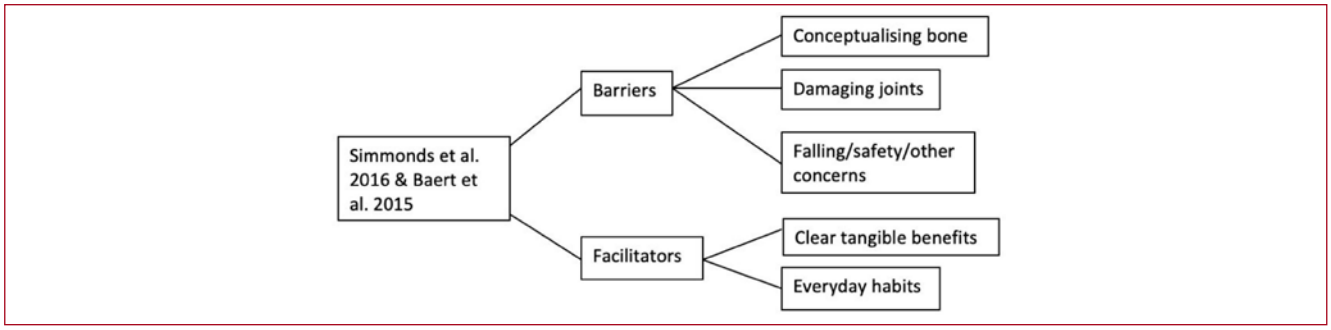

Figure 2. Synthesised themes identified in two studies[20,21] examining perceptions of exercise for bone health.

methodological quality of studies, not to exclude, rather to rate the credibility of the findings.

Results

Study selection

The initial search strategy yielded 1209 potentially relevant papers were identified (Figure 1). Following deduplication, this was reduced to 788. 747 papers were excluded based on titles and abstract and 10 papers could not be retrieved. 31 papers were assessed for eligibility and 2 were included. From the references of papers assessed for eligibility, 197 further papers were identified, 2 papers could not be retrieved and 10 were assessed for eligibility. 2 further papers were included. Therefore, in total 4 papers were included in the review (Figure 1).

Study characteristics

Two studies specifically focused on participants' experiences of taking part in exercise to improve bone health[18,19], while the other two concentrated on perceptions[20,21] (Table 1). Three studies investigated the older adult population (age 65-88)[18,20,21] and one explored the younger female population (ages 20-35)[19]. Two studies used individual interviews[18,19] and two utilized focus groups[20,21].

One study explored the experiences of older women following a 12-week individualized, brief (10 min, 2-4 times per day), home-based muscle strengthening and balance exercise program delivered and monitored using an Amazon Echo Show 5 device (Alexa)[18]. Another study interviewed women who took part in a randomised controlled trial looking at the effectiveness of two supervised, high-intensity, exercise programs (impact and resistance training) and an unsupervised low-intensity exercise control[19]. Of the 2 studies considering perceptions, one sought views from older women with osteoporosis about the barriers and motivators to being physically active with their condition[20] and the other specifically explored the acceptability of high-impact physical activity[21].

All studies scored 8 or more out of 10 on the CASP Tool. Only 1 specifically addressed the relationship between the participants and the researcher (bias/influence)[19], 1 did not member check their themes[20], 3 had multiple authors review the analysis[18,19,21], 2 explained their use of interviews/focus groups[18,20].

Themes

Quotes extracted from the studies are presented in Supplementary Data.

Older women's perceptions of physical activity to improve bone health

The two studies that investigated the perceptions of older females towards PA had similar themes that aligned and were synthesised in Figure 2[20,21]. Those themes that did not synthesise are presented in *Supplementary Data (additional themes from Baert et al.[20])*, and included *not wanting to learn new exercises* as they adapt their activity instead, *heterogeneous advice* from health professionals and *negative experiences with the weather*[20].

Perceived barriers to physical activity in those with osteoporosis

The theme of '*safety*' emerged from both studies as the main barrier for older females as many perceived an increased risk of falling when undertaking PA[20,21]. This included their conceptualisation of bone as being brittle, concerns about damaging joints and falling while exercising.

"I'm scared that I will fall during exercise. It hinders me to move. I had a spontaneous fracture of the hip"

Previous fallers were hesitant towards the idea of participating in high-impact PA. Although patients discussed a desire to participate in high-impact PA if holding on to a stable object, providing a greater sense of safety.

"As long as I'm not going to fall, I will do it [laughs]"

Health care professionals' advice towards PA, a theme

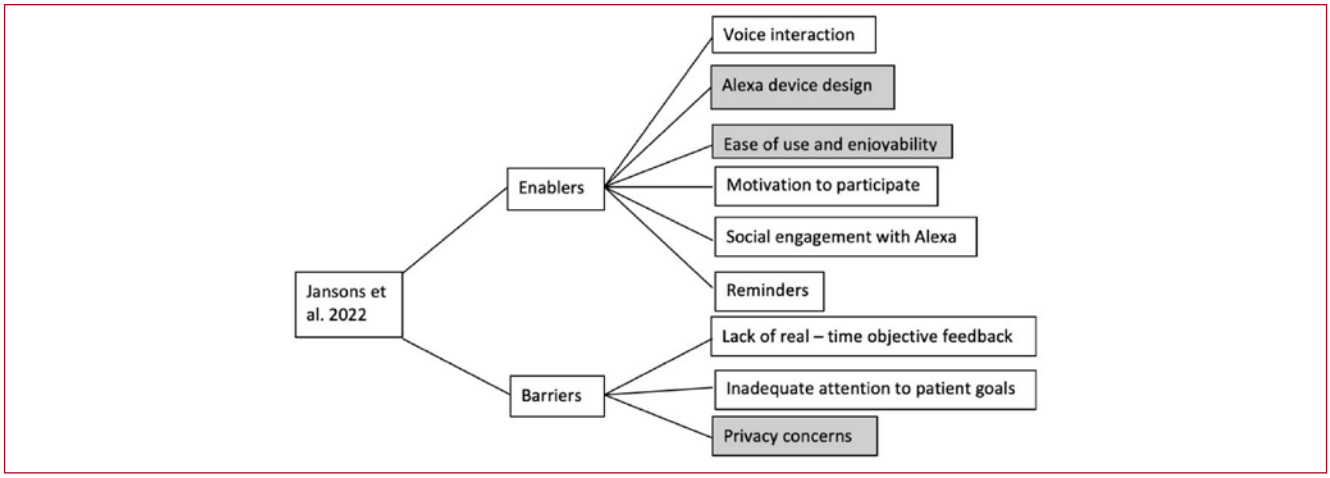

Figure 3. Themes identified in Jansons et al. 2022 study[18] (boxes highlighted in grey are themes not pertaining to the exercise intervention itself but the Alexa device).

seen in Baerts study[20], can play a substantial role in preventing older females from participating in PA. Multiple participants shared how their practitioner advised them not to participate in PA or restricted them to low impact PA.

"I was told not to exercise too much, and I have to take a rest now and then"

However, participants claimed they would participate in such activity if:

"It was on the doctor's recommendation and it was confirmed safe to do so"

If higher impact PA was advised by health care professionals, other older women would perceive the intervention as safe.

"I would do it if it was on the doctor's recommendation, yes. If he thought I was capable of doing it…I wouldn't undertake it unless I was advised. Or unless I confirmed it was safe to do it"

Facilitators towards physical activity in women with osteoporosis

Being able to integrate the exercises into activities of daily living appealed, making exercise an *everyday habit*.

"it's just got to become part of a routine"

"That's something you could do as you're walking around…once you got into it, I suppose, you could do it really just without thinking"

Clear, *tangible benefits* were important, as changes to bone were not visible.

"If another x-ray was taken and I could see a difference…. after a few days you can feel a slight difference so you know what you're doing is right"

The desire for feedback within a supervised exercise session was expressed as a facilitator for older females to participate in higher-impact PA and in terms of safety. Attending supervised group sessions with a variety of high-impact exercises (to avoid tedium) was also seen as a facilitator to higher-impact PA.

"I think it would be good to go … and have it all explained, as once you know how things are working, that sort of helps you to look after yourself. Perhaps meet up sort of once a month just to keep you going really…"

Supervised classes allow for instruction and feedback instilling confidence in older females when engaging in high-impact PA.

Older females' experiences with home exercise program

Enablers

Jansons et al. (2022) asked for experiences of using an Amazon Alexa device to deliver an exercise intervention to older adults[18]. Participants identified various enablers for participating in the at-home exercise intervention (Figure 3). Using Alexa voice interactions to participate in the exercise program was expressed as an enabler,

"didn't need to be close to it to do the exercises" and "could do them from a distance"

The Alexa device possesses an element of social engagement in which participants found to be beneficial.

"(I enjoyed) that someone was talking to me when you live on your own"

Participants found the screen and voice compatible reminders the Alexa delivered to be a facilitator within the intervention,

"Yeah, I found that it actually made you commit to doing it. Because it would give you reminders, you kind of felt obligated to complete it, you wouldn't just be going …Oh, I'm too busy, or I can't be bothered…. So I found that was really good. It sort of made you commit to it"

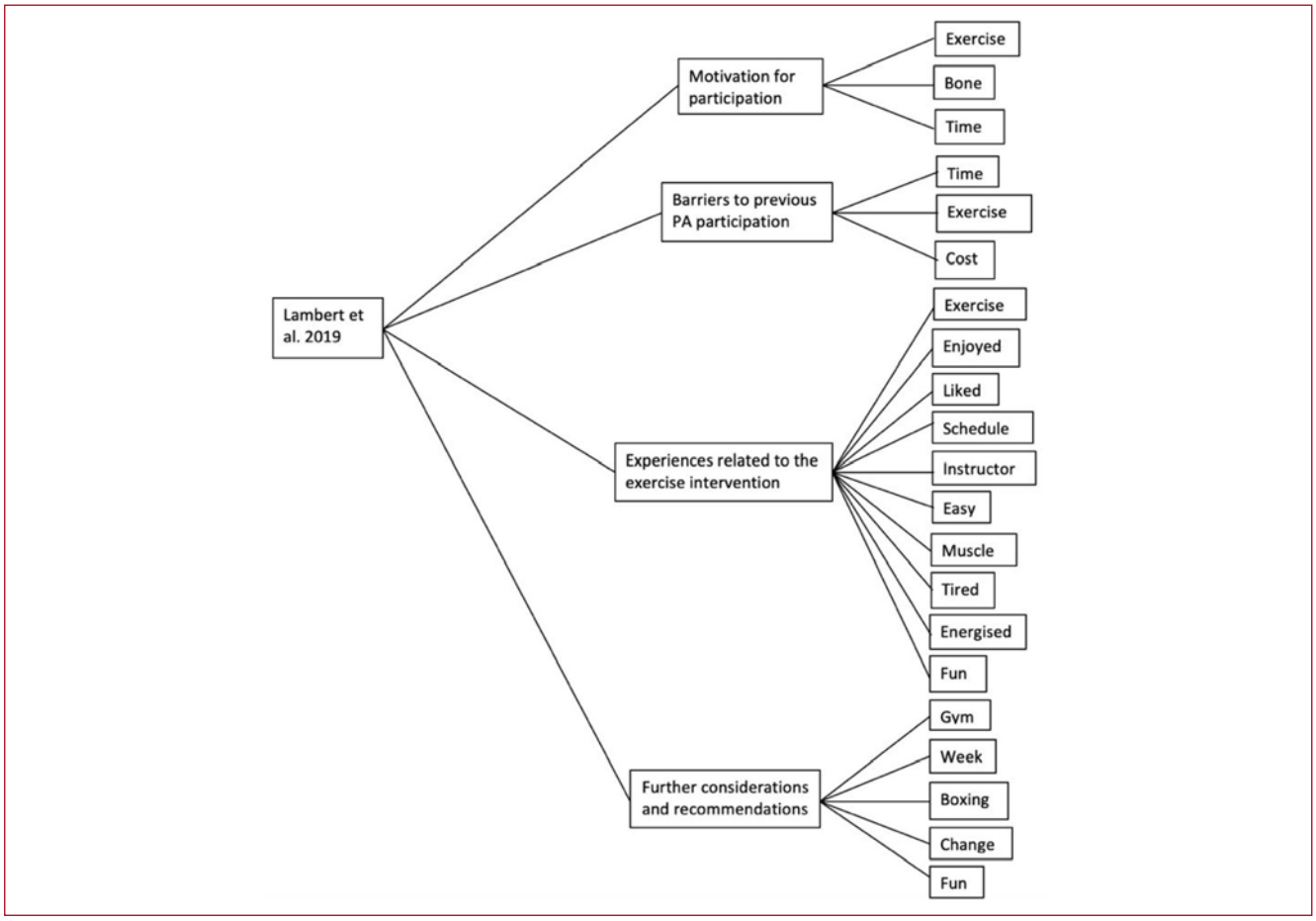

Figure 4. Themes identified in Lambert et al. (2019) study[19].

Barriers

A lack of real-time objective feedback throughout the exercise program was noted as a barrier. The value of feedback pertaining to exercise technique while engaging in the exercise intervention was expressed.

"I used to do some of these exercises with the exercise physiologist, I know how you're meant to do them. But for some people, they probably need a little bit more guidance on some of the exercises. Like I know you do say 'hold your bum in' or whatever, but some of them it's quite important that they do it correctly"

The need for the intervention to educate participants as to why certain exercises are beneficial was a component older women felt was missing. Some participants, who were not used to exercise, were unsure why certain exercises were incorporated into their program.

"I'm guessing that the balance is good for someone my age because falls can be a problem as you get overzealous, sort of thing. But the explanation of the value of what we were doing would be good, the physical value"

Young adult females' experiences with exercise intervention

Facilitators

When focusing on younger females' experiences with exercise interventions to improve bone health, different themes emerged than those reported by older women (Figure 4). Lambert et al. (2019) highlighted motivation as a factor regarding participants' participation in supervised high-intensity impact training (IT), high-intensity resistance training (RT) and the controlled unsupervised low-intensity exercise (CON)[19]. These exercise interventions possessed an element of accountability for participants which was also highlighted as a motivational factor, knowing that someone was going to check on your progress.

"Just trying to stick to a particular exercise as I am not very good at sticking to any form of program so it kind of was a good motivational tool to have to know that I am coming back in 10 months' time to see what's different and if anything has changed"

Positive improvements made during the intervention were discussed with respect to participants' experiences.

Many participants enjoyed how the RT challenged them and how they saw improvements when progressing to heavier weights. Not only did the RT and IT group enjoy acquiring a new skill, they also got satisfaction in feeling changes over time.

"seeing the progression by the week"

Participants also noticed aesthetic improvements while participating in the exercise interventions. Many expressed how they felt themselves getting stronger and overall feeling better from participating in the intervention. A participant from the RT group expressed how she felt,

"Definitely strength, I think I got a lot stronger and sort of proud of that in that I felt stronger"

Another participant noted a weight loss while participating in the intervention,

"I've definitely lost weight since last year, since I was weighed in. And I think that's the same thing just having that regularity of having to move and have exercise as a part of your weekly regime"

The RT and IT group also mentioned their positive experiences with the level of supervision within the intervention.

"I didn't feel like I was pushed or that I was held back, I felt like it was very matched which was good. And then you know correction of form as it got heavier and things like that was really good as well"

"I was really surprised at how good it felt how quickly and how strong…it kind of took me by surprise"

Barriers

A common barrier of boredom and lack of interest emerged. The IT group explained how their lack of interest acted as a barrier to them previously participating in any form of exercise. A participant in the IT group explained,

"I wasn't ever able to really find something that interested me. I thought of it looked kind of boring"

Some found it too easy.

"Well I was expecting it to be more intense", "it was too easy for me"

Recommendations to 'improve' the intervention

When asked about changes to the intervention, participants felt engaging in the program twice a week was a facilitator to their regular participation, and they would be

"happy to do it more frequently but also felt like two was a bit more manageable for scheduling like three would have been a bit harder to fit in"

Most participants gave little feedback regarding changing the intervention as they thought it was well structured and appreciated how they were eased into exercise.

Discussion

To the author's knowledge this is the first systematic review focusing on the perceptions or experiences women have towards physical activity and exercise interventions to improve bone health. Through quantitative research, exercise interventions such as the LIFTMOR study, have proven to be effective at improving bone health[11]. However, there is a lack of knowledge regarding participants thoughts towards such interventions. A greater insight into women's perceptions or experiences regarding exercise and PA interventions can provide insight into uptake and adherence for interventions.

It is clear older females are more worried about safety concerns, such as falls and fractures, and this can be a significant barrier to exercise. Fear of falling or of injury were paramount in older people's minds, either through concern they might do the exercises incorrectly or that they would not have the ability to do the exercises safely[20,21]. This kinesphobia has been seen in other studies in people with osteoporosis[9]. This fear is also seen in fall prevention programs as participants believe themselves to be more vulnerable to falls and are aware of the aftermath[22,23]. However, older women noted they would be willing to participate in high-impact PA if there was a way to reduce the likelihood of a fall, in particular, with supervision[20,21].

One of the main facilitators to engaging in exercises to improve bone health is feeling tangible benefits. In terms of strength or balance, benefits can often be felt fairly quickly, but in terms of knowing the effects on bone, these are not noticeable and there can be a perception of lack of improvement. If women believe PA is not producing tangible or beneficial results then there is no sense in continuing with it[20]. Simmonds et al. (2016) participants explained if they saw tangible results, they would be more willing to participate in higher impact PA on a regular basis[21]. Although older females may not see changes to their bone, they are knowledgeable in the benefits PA has for their bone health and can feel the difference in their strength or steadiness. Previous research on fall prevention addresses how participants appreciate information regarding the physical and psychological benefits exercise can have for them[23]. Education regarding benefits exercise and PA interventions could in turn change females' perceptions regarding PA.

As has been previously published, heterogeneous advice from health care professionals can lead to avoidance of activity[7]. Some people with osteoporosis have been advised by their physicians not to be physically active or have been given restrictions to types of PA they can participate in[7]. Many older females consider their practitioners the primary source of knowledge when it comes to health and will adhere to their advice. Females have demonstrated their willingness to engage in high-impact PA only if recommended by a doctor[21]. Bunn et al. (2008) highlight how health care professionals have an influential role in the advice they give their older patients[23]. Knowledgeable professionals, in terms of trained instructors, were also discussed with regards to supervision of exercise sessions[21,22]. If older females feel safe while engaging in PA, they are more likely to gain confidence and continue with PA and perhaps a key facilitator is supervised classes, or regular check-ins, with

trained instructors to ensure they are maintaining good technique and progressing as they should. The presence of an instructor can have a motivational role and one with empathy and training in motivational techniques can improve adherence[24]. Older adults' attitudes often affect the level of engagement and adherence to exercise classes, therefore instructors can have a direct effect in changing these attitudes[24]. Of course, regular check-ins and supervision provides some accountability for the participants, where they expect someone to check on whether they are doing the exercises[18,19]. Therefore, if designing interventions that are unsupervised, an aspect of accountability should be embedded within the program to help improve adherence and participation.

The main reason for older and younger females not participating in PA or exercise is due to the lack of enjoyment[19]. Younger females express how they must be interested in the type of exercise to engage and adhere to it[19]. Enjoyment of exercise has been deemed valuable if sustained participation is desired[25]. Females like to be challenged and achieve a sense of accomplishment when engaging in exercise[18,19]. Similar findings are seen in Valenzuela et al. (2018) study in which fall prevention participants benefited from feeling physically and cognitively challenged within the exercise intervention[26]. As expressed by older females, a variety of exercises and difficulty levels within the intervention would help prevent boredom and keep them more engaged[20,25].

Younger women differ from the older women in these studies, in their experiences of exercise, as they are more focused on the physical differences they feel or see from engaging in exercise[19]. Many focused specifically on the aesthetic improvements they saw while participating in an exercise intervention[19]. Quantifiable progress in weights was highlighted as a way in which improvements were evaluated, as seen in Lafond et al. (2019) findings[25]. On the other hand, older women focused on the social "human" engagement the exercise program offered them[18]. Previous research has addressed how individuals within a fall prevention program emphasised the level of enjoyment they found in meeting new people[23,26].

It is important to address the limitations within this systematic review. When focusing on the methods of this review, retrieval of relevant articles was poor as only 50% of the papers included came directly from the database search. However, by reference checking the included studies and use of other sources a further 50% of the papers were picked up ensuring that studies were not missed. Furthermore, 10 papers were unable to be retrieved. Consequently, only four studies were included within this systematic review. This review specifically focuses on the female population thus the findings may not be as rich, however, men often have very different views on exercise and few studies have included men, so this was felt to be the correct strategy for this review. The main author of this systematic review presents themselves as a novice qualitative researcher thus having limited research experience. Although this systematic review possesses many strengths, results should be interpreted with caution.

Implications for practice and further research

Although findings may not be generalizable, the results of this systematic review can highlight important considerations for promoting exercise and PA to women with osteoporosis or those wishing to maintain or improve bone health. Findings from this systematic review highlight the positive views and experiences women possess after completing an exercise intervention. Studies have supported the idea that previous participants of exercise or PA interventions ('peers') can be potent motivators for others to participate in similar interventions[27]. This may help address the 'fear' that many have of injury or falls during an intervention. Supervision, with trained instructors, will create a sense of safety, care and support. Healthcare professionals should support patients on diagnosis of osteoporosis with sound and supportive advice to move more and seek effective interventions to improve strength, provide impact and prevent falls[7].

However, further research is needed to obtain deeper insight into females' experiences and perceptions specifically using focus groups, as well as interviews, to ensure the robustness of findings. It would also be of benefit to explore views and perception of men and of other ethnicities as the included studies focused on mainly Caucasian women. Perceptions and experiences of exercise or PA to improve bone health could vary across different cultures, therefore more research is required[28].

Conclusion

Exercise and PA interventions are only beneficial for improving bone health if there is sufficient adherence. Researchers are aware of the positive benefits exercise can have on bone health, but the findings hold less value unless health professional advice is supportive and women are willing to engage in exercise. This systematic review highlights supervised classes, engaging exercises, and safety as important aspects for consideration when designing an intervention aimed at improving bone health. If exercise and PA interventions take into consideration females' perceptions and experiences, uptake and continued participation should be seen.

Disclaimer

Prof. Dawn Skelton is co-Editor-in-Chief of the Journal of Frailty, Sarcopenia and Falls. The manuscript underwent peer review process by independent experts.

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Supplementary Data. Quotes separated by themes and authors.

Simmonds et al. (2016)[21]		
Themes	**Subthemes**	**Quotes**
Barriers	Conceptualising bone	1. Pain felt in bones *Oh my God, sometimes if I even move, or lay down, it's too hard for me to move it, because I have got pain here, and over the fingers and going stuff, and making too much noise!"* 2. Confusion between bone and joint health *"Well, I've always heard about brittle bones and I've started taking glucosamine."*
	Damaging joints	1. Would they consider higher impact physical activity *"I'm not sure, but I'd rather not try it!"* *"No, 'cause you've got those false hips haven't you? It's your hips that would do it."* 2. Consultants advice *"It's since my surgery, or since my knees became bad, that I don't run, and the consultant has advised me not to go running. He said, 'Running for you, now, would be stupid.' That was how he put it [laughs] ... I think the consultant is also worried about me damaging my knees. I think I'm very careful because I know it's a prosthesis in there...I used to jump...but since my surgery, I do more low-impact exercise... because the knee replacement ... it's a major operation."* 3. Jumping within home environment *"I would do it if it was on the doctor's recommendation, yes. If he thought I was capable of doing it... I wouldn't undertake it unless I was advised. Or unless I confirmed it was safe to do it."*
	Falling/safety/ other concerns	1. Previous fallers expressed how they would jump if holding onto an object and/or they were being supervised by a professional *"As long as I'm not going to fall, I will do it [laughs]."* *"Okay, yes, because if you were holding onto a chair – is it safety that you're worried about?" (Int)*
Facilitators	Clear tangible benefits	2. Tangible results and feedback available *"It's difficult to say because I think if it was visible ... if ... I don't know. If an x-ray was taken of my legs and then after say 3 months of doing this jumping another x-ray was taken and I could see a difference if that's what they said they were going to do then fine, I'd probably do it. But it's like exercising, you know, once you've had the surgery you have to exercise to get better, get your joints moving. You can feel it. After a few days you can feel a slight difference so you know that what you're doing is right. I don't know if it would be the same for sort of ... if there was a reason for it that I could see..."*
	Everyday habits	1. Participant who continued with her physiotherapy program explained the significance completing the exercises had for her *"Because I can see that they are benefitting me...it's just got to become part of routine ... my neck this week, I can ... feel that it's a lot looser ... to keep it mobile, I need to keep moving my head around... don't want to get into old, old age and not be able to do anything ... Having to go in to a home and ... be looked after ..."* 2. Integration of higher impact physical activity into older adults' activities of daily living *"I suppose if I thought it was doing me good ... I mean it's not that hard, is it, ten jumps every so often. That's something you could do as you're walking around, sort of thing. Every now and again I'll have a go. Once you got into it, I suppose you could do it really just without thinking."* 3. Physiotherapy exercises found difficult to perform at home; *"Yes, I'll do this at home", and you get home and you think, "I'll just do that", and you might do it the next day as well and then the day...you say, "I'll do it presently", and you don't get around to doing it."* 4. Supervised, one-off, group session offering a variety of higher impact exercises *"I think it would be good to go ... and have it all explained, as once you know how things are working, that sort of helps you to look after yourself. Perhaps meet up sort of once a month just to keep you going really..."*
Baert et al. (2015)[20] quotes relating to themes in Simmonds et al. (2016)[21]		
Themes	**Subthemes**	**Quotes**
Barriers	Conceptualising bone and PA	1. PA mentioned as activities involving movement of the body such as administrative work, *"I am still working full time doing paperwork."*
	Falling/safety/ other concerns	2. Fear of falling perceived as a barrier related to osteoporosis *"I'm scared that I will fall during exercise. It hinders me to move. I had a spontaneous fracture of the hip."* 3. Barrier to physical activity regarding the lack of financial resources *"I don't have enough money for all my osteoporosis treatments. Where would I get the money to spend on PA?"*
Facilitators	Clear tangible benefits	4. Osteoporosis patients perceived physically active as beneficial for their physical health *"It is good for the heart, our lungs, muscles and blood circulation"*
	Everyday habits	5. Older females said they were willing to modify their PA behavior *"I would like to have an exercise bike so I could train inside the house."*

Supplementary Data. *(Cont. from previous page).*

Additional themes from Baert et al. (2015)[20]		
Themes	**Subthemes**	**Quotes**
Barriers	Adapting PA	6. Reduction in intensity and/or volume of physical activity *"I do everything more at ease and at my own pace"* 7. Need for assistance in activities of daily life *"I ask other persons to help me with household activities, transportation and maintenance."* *"My partner and I divide the household tasks"* 8. Osteoporosis as a perceived barrier as it was the reason for adapting physical activity *"I adjust my position when I'm gardening or doing household tasks."*
	New skill	9. Not wanting to learn a new type of physical activity *"I don't want to learn something new. I'm too old."* 10. Regret towards not learning activity *"I think swimming would be good for me, unfortunately I've never learned how to swim and now it's too late."*
	Advice given by health professionals	11. Heterogeneous advice from physicians regarding physical activity *"The doctor told me to move more: walking, biking, swimming, fitness…"* 12. Advice towards being less physically active or restricting in the type of physical activity *"I was told not to exercise too much and I have to take a rest now and then."* *"The doctor advised me not to ride a bike."* *"My general practitioner said I didn't have to sit still and that every type of exercise is good for me. The specialist gave me the same advice and added that I have to travel to sunny places"* 13. Limited information from doctor concerning physical activity *"The doctor gave me medication, that's it."* 14. Professionals need to be more confident in their advice *"I would be stimulated if someone who is specialized in my medical condition would give me a good follow-up and proper advice. What I have to do to get rid of my pain without feeling pain in the mean while."*
	Negative experiences with PA	*"The exercises from the physiotherapist aren't doing any good for me."* *"I'm exercising less because of the pain."* *"Every move I make, I'm experiencing pain."*
	Weather	15. Weather perceived as a barrier to physically active *"I'm not averse to being physically active, except when there is a bad storm outside."*
Jansons et al. (2022)[18]		
Themes	**Subthemes**	**Quotes**
Enablers of interacting with the Alexa	Voice interaction	1. Voice interactions to engage in the exercise program was expressed as being user-friendly *"Yeah no, it's good. You don't have to touch it."* *"Oh yes, I didn't need to be close to it to do the exercises. I could do it from a distance and it responded to my answers."*
	Alexa device design	2. Convenience of the Alexa device design to participate in exercise program *"Anyway, it can stay where it is, you know what I mean? I don't have to transport it around the house and the volume is important that you can adjust the volume. It is kind of like a more-or-less permanent fixture in the house. So that was good- it was inobtrusive and small enough but usable enough if you know what I mean."*
	Ease of use and enjoyability	3. Enjoyability and simplicity of Alexa and Buddy Link *"I enjoyed using it. I found Alexa (and the Buddy Link software program) very easy to use."*
	Motivation to participate in the exercise program	4. Motivation to participate in exercise program *"(An exercise program is difficult) to do… because sometimes you get lazy and you don't really want to do things. But if you're getting directions and instructions (from the Alexa) along the way, you're doing it without an effort because it's gentle."* *"No. I think the thought behind it is good and I can only speak personally for myself that it made me more interested and motivated to do (the exercise program). Because if you're by yourself all the time and you're not mixing with other people, or in a group situation, and I used to go to group exercises, to keep yourself motivated to do exercises several times a day when you get to the age range that I'm in."* *"I did the exercise because she (Alexa) always asks me (do you) want to do it again? So, I did it again, but all the other times when I said I'll do it again it's because I was not happy with myself and I wanted to improve it. It's a really thought through program."*
	Social engagement with Alexa	5. Aspect of social "human" engagement the Alexa offered *"I would use that device. …I really like this because she's always asking, 'Are you ready?' So, you always have to give a response. You can't just say oh well, I'd like to quickly go and get the bin out or what. You just can't."* *"(I enjoyed) that someone was talking to me when you live on your own."* 6. Participants with visual issues engaging with an asynchronous telehealth platform *"Yes, that's convenient. Especially now that I've had the cataract operated on, it's quite hard for me to read small print so I've got to find glasses which are never far away."*

Supplementary Data. *(Cont. from previous page).*

	Screen and voice compatible reminders	1. Motivation to participate in exercise program from screen and conversation-based interactions *"The advantage of having it there, knowing that it was going to remind me to do my exercises was a good thing, because I do have a physio app on my phone, but I have to actually go onto it to use it, where this actually would be reminding me. I feel very guilty if I didn't do it."* *"I thought it was a great way to be reminded and would definitely influence me to exercise more. So I thought it was a very good thing from that point of view."* *"Yeah, I found that it actually made you commit to doing it. Because it would give you reminders, you kind of felt obligated to complete it, you wouldn't just be going ...Oh, I'm too busy, or I can't be bothered.... So I found that was really good. It sort of made you commit to it."*
Barriers to interacting with the Alexa to participate in the exercise intervention	Lack of real-time objective feedback in an asynchronous digital health approach	2. Lack of feedback and reassurance towards correct exercise technique *"You don't get feedback, so for somebody who's not maybe that good at doing their exercises, I don't know how you would be able to but it would be great if they would get a bit of a feedback on it, whether there's a physical way you could get somebody to do the exercise on a certain spot and put the camera on a certain spot and then it would be able to measure – or what, I don't know. Maybe a future version."* *"Yeah, even if it was saying 'Too fast. Too fast,' because that's what I tend to do, everything too fast. Or you know, it might say 'Just one more,' you know, that sort of thing. Yeah, I think that sort of feedback would make it even more engaging for people."* *"I used to do some of these exercises with the exercise physiologist, I know how you're meant to do them. But for some people, they probably need a little bit more guidance on some of the exercises. Like I know you do say 'hold your bum in' or whatever, but some of them it's quite important that they do it correctly. So it's tricky because the first time they do it they need the full instruction and then after that you're just say reminding them what the exercise is, so."*
	Inadequate attention to patient goals as an asynchronous digital health approach	3. Need for exercise program to include insightful information on the purpose of exercise and to incorporate participants goals *"No, it's always good to have a real human being to deal with. But as a substitute, I think it's quite good. The other thing was I did get bored. You brought in some more exercises to give some variety and I suggested explaining why we were doing these. I'm guessing that the balance is good for someone my age because falls can be a problem as you get overzealous, sort of thing. But the explanation of the value of what we were doing would be good, the physical value."*
	Privacy Concerns	1. Privacy concerns when Alexa device is turned off *"Well I had the camera turned off, so I'm not sure – and because I live alone, there's not too many conversations going on around a machine, but if you had a private conversation you probably wouldn't have it in front of Alexa. But I don't know. If you haven't turned her on I don't know if there's any recording happening anyway. I don't know. I don't know of that privacy."* *"I have turned off the camera except talking to you now. Yes, I suppose with the camera on I would have issues with that, in general, not from Deakin University, but just from Amazon up there in the Cloud, and who else is on it and so on." "It did concern me, because you don't want to think that you're being listened to all the time and watched all the time, however it was alright once I found where to turn off the camera."* *"Well, I'm a little bit—I mean in terms of the exercise and stuff not really, but if I had to—like, if it was a different kind of program where it's involving a lot of private things like medical stuff or opinions about things or whatever I might, yeah, think twice about that because the stuff that it's Alexa or a Google Home thing where they do—you don't know where your information is and all that sort of thing. Yeah, I mean I'm a bit, not suspicious, but I'm wary of the devices just generally, but in terms of just data for the exercise it's not an issue for me. It's only if it's asking personal information."*
Lambert et al. (2019)[19]		
Themes	**Subthemes**	**Quotes**
Motivation for participation	Exercise Bone Time	1. Motivation to participate *"I wanted to become more fit and also I have a family history of osteoporosis so I was worried about getting it and thought I could do whatever was available to me to try and prevent it." (IT)* *"It seemed like a good opportunity to get fit with some free exercise." (RT)* *"Just trying to stick to a particular exercise as I am not very good at sticking to any form of program so it kind of was a good motivational tool to have to know that I am coming back in 10 months' time to see what's different and if anything has changed." (CON)*
Barriers to previous PA participation	Time Exercise Cost	2. Lack of motivation and interest in the type of exercise addressed as barriers to participation *"I wasn't ever able to really find something that interested me I thought of it looked kind of boring." (IT)* 3. Lack of time identified as barrier to exercise participation *"Definitely not as much after uni came in... time issues and a little bit of self-laziness." (RT)* 1. Barriers as to why participants within the CON group did not partake in exercise previously *"I've never really had the opportunity to. A lot of them do cost a fair bit of money and money is never something that I really had floating around for things like that." (CON)*

Supplementary Data. *(Cont. from previous page).*

Experiences related to the exercise intervention	Exercise Enjoyed Liked Schedule Instructor Easy Tired Energised Fun	1. Majority of participants had a preference for boxing program opposed to jumping exercises. Clear notion of achievement from learning new skills was also expressed *"I think it was nice to see, you know like learning a new skill and getting that ability and seeing the progression by the week. You know it keeps on moving up and changing." (IT)* 2. Challenge the resistance training encompassed and quantifiable progression of weights was see as being enjoyable *"Overall I think I enjoyed it. I never had worked with weights before so I suppose I was interested to learn how to do it and then when I could do it that was really exciting. Yeah I never thought that it would be something I could easily pick up but I guess I was very surprised." (RT)* 3. Program easy to follow and fit well into participants lifestyles *"I think they were easy to do. It wasn't too intrusive in my life which was awesome. I could pretty much do it whenever I wanted to do it. It was twice a week so that was good. I find that like if I'm only doing it once a week, I don't really stay on track and I get quite bored. So overall yeah I found it quite good." (CON)* 4. Intervention was noted as being less intense than females expected *"Well I was expecting it to be more intense but … I liked it, that it was light and I didn't feel tired after doing it." (CON)* *"I think it was too easy for me." (CON)* *"Any time you had slight technique issues there was someone always there to correct that which was fantastic, you were supervised at all times which was really, really good and yeah I enjoyed it." (IT)* *"I didn't feel like I was pushed or that I was held back, I felt like it was very matched which was good. And then you know correction of form as it got heavier and things like that that was really good as well." (RT)* *"You could really just fit it in with whatever you wanted." (IT)* 5. Although not constantly supervised, participants in home program felt guided throughout the intervention *"That's the thing I went through the book and I went through all the exercises the instructional videos were awesome, as well as like the print outs that I was given, like it was quite easy for me to replicate the things that I had to do and I thought it was good." (CON)* 6. Muscle soreness was mentioned *"At the beginning I was sore but after a while it was good. I felt better, like you always feel good after exercise. You know when you don't particularly want to go that week but you still go and then you feel good." (IT)* *"In the earlier weeks there was more muscle soreness when I was sort of adjusting to the exercises as a whole and then afterwards I suppose there would have been a little bit but generally it got less throughout the year as my body got used to the movement." (RT)* *"Physically, yeah not too bad. I did get sore muscles for the first month on and off I think that was just my muscles getting used to doing those particular exercises. And then as months went on it was, I guess, they got used to it and I wasn't as sore as I was." (CON)* 7. Two groups talked of the 'mental health' benefits from the exercise intervention *"Definitely noticed that I am a lot more energetic after the sessions and my concentrations better and just generally feel better(it) took a lot of tension, cleared my head, yeah, a lot of pleasant surprises that I wasn't expecting." (IT)* "I think because you feel like you've achieved something it was like emotionally and mentally you felt better." *(RT)* 8. Changes participants identified *"Definitely strength, I think I got a lot stronger sort of proud of that in that I felt stronger." (RT)* 9. Shift in participants attitude towards exercise *"I think my attitude towards exercising probably yeah, I feel like it's less of a chore it's more enjoyable. I guess it's just finding what you like really. Yeah a little bit less daunted by the idea of having to do physical activities." (IT)* 10. Esthetic improvements mentioned *"I've definitely lost weight since last year, since I was weighed in. And I think that's the same thing just having that regularity of having to move and have exercise as a part of your weekly regime." (CON)*
Further considerations and recommendations	Gym	1. Continuation with boxing training whether at home or in organized classes *"Again it's trying to find something that is equally as convenient to fit into my work and lifestyle but if I can find that then absolutely I would keep going. Somewhere close by and probably the same sort of frequency two to three times per week." (IT)* 2. Barriers of time and money to future exercise participation *"The only problem that might stop me is paying for it when it comes to costs because my schedule is so chopping and changing, oh yeah that and the timing." (IT)* 3. Duration and frequency of the session liked by females, and the two sessions a week was seen as a facilitator to regular participation *"Yeah I'd be happy to do it more frequently but also I felt like two was a bit more manageable for scheduling like three would have been a bit harder to fit in." (IT)* 4. Little feedback regarding changes to exercise interventions *"I don't really think that I would change them because they were very well paced. You start off very light and easy and initially it feels very light and easy and it gradually builds up but the progression is in such a way that it feels beneficial and it doesn't feel like you're overburdening yourself. So I don't think that I would change anything about it." (CON)* 5. Many females would recommend resistance training due to how it made them feel *"I was really surprised at how good I felt how quickly and how strong …it kind of took me by surprise how much I enjoyed it. So definitely would recommend it to friends who have never done weight training before." (RT)* 6. Females would recommend intervention to a friend based on the ease of the program *"I think it's great it just fits into your lifestyle quite easily." (CON)*