Original Article

To Compare the Effects of Different Schemes on BMD in Postmenopausal Women, and Provide a Scientific Basis for Physical Training Prescriptions that can Improve BMD in the Elderly Population: A Meta-analysis

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Abstract

Aim: The objective of this study is to evaluate the impact of various strategies on bone mineral density (BMD) in postmenopausal women. The aim is to establish a scientific foundation for developing exercise recommendations that can enhance BMD in older individuals. <meta-analysis> **Material and methods:** Google was used to gather results from randomised controlled trials that tracked postmenopausal women for over six months in order to assess the effect of exercise on bone mineral density (BMD). We performed a Bayesian randomised network meta-analysis. **Results:** After sifting through 29,86 records based on titles and abstracts, we were able to add 50 trials with 3,673 participants in our network meta-analysis after they matched all of the inclusion criteria. With a mean age range of 51.92 to 80.76 years, the sample size varied from 16 to 239 people. Ten studies (20%) have excellent quality, thirty-three (66%) have moderate quality, and seven (14%). There was good convergence across all models. All results have parameter PSRF values close to 1, which means that convergence is going well. When comparing the comparison groups for all outcomes, discrepancy between direct and indirect estimates from the node splitting analysis did not reveal any significant differences. The following factors were associated with improvements in BMD at LS: multicomponent exercise (0·01 g/cm2), resistance training (0·01 g/cm2), mind-body exercise (0·01 g/cm2), lower impact exercise (0·01 g/cm2), high impact exercise (0·02 g/cm2), and whole body vibration (0·01 g/cm2), all with 95% CrI values ranging from 0·00 to 0·03. No longer was there a link between high-impact or low-impact exercise and enhanced BMD as compared to control when 7 low-quality studies were eliminated. **Conclusion:** This NMA demonstrates that exercise treatment significantly enhances bone mineral density in postmenopausal individuals. Furthermore, it shows that the magnitude of the influence varies depending on the duration of the intervention, the age of the participants, and the specific outcome being studied. Clinicians can refer to the study's graded exercise interventions to choose the most effective personalised exercise routine for increasing bone mineral density (BMD).

Keywords: BMD, Postmenopausal Women, Physical Training, Elderly Population.

Introduction

After menopause, there is a considerable decline in bone mineral density (BMD), which puts postmenopausal women at a much greater risk of developing osteoporosis and experiencing fractures. According to estimates, almost one-third of women who have finished may experience a condition known as osteoporosis. Osteoporotic fractures are a significant concern, affecting roughly 9 million people annually, with women accounting for around 61% of these cases. Consequently, both nations and society as a whole experience the impact of the financial and health burden caused by osteoporotic bone fractures, resulting in unnecessary morbidity and mortality rates.[1-4] Clinical

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practice prioritises several forms of physical exercise, including endurance exercise, resistance exercises, balance training, and dynamic impact activities, to uphold a high level of bone mineral density.[5,6] Several meta-analyses and systematic reviews have also examined the ability of these exercises to prevent bone loss or promote the increase of bone mass. The meta-analyses studies showed that exercise did not effectively reduce the variances in bone mineral density (BMD). This could be partly due to the significant differences in exercise routines and the heterogeneity of factors across the participants.[7-11]

Hormonal changes during menopause are a contributing risk factor for bone loss and osteoporosis. This paragraph discusses the various key aspects of the decrease in oestrogen levels and the associated dangers in women after menopause.

Hormonal Changes: Oestrogen mitigates the detrimental effects of high blood pressure on arteries. Therefore, as oestrogen levels decline following menopause, the protective effect is no longer there. Oestrogen plays a significant role in the regulation of bone density. Decreased oestrogen levels lead to accelerated bone density loss.

Osteoporosis Risk: Postmenopausal women face an elevated risk of osteoporosis, characterised by reduced bone mass and degeneration of bone tissue. Furthermore, low levels of oestrogen heighten their susceptibility to cardiovascular diseases and some types of cancer. Sedentary osteoporosis increases the susceptibility to fractures, with the majority of fractures occurring in the femur, spine, and wrist.

Bone Mineral Density Testing: Dual-energy X-ray absorptiometry (DEXA or DXA) is the most used of all the methods in the DXA-related bone mineral density (BMD) scans. This is an essential non-invasive and low radiation type of imaging that uses X-ray signals to evidence testing bone density[1] at different sections, such as in the hip and spine.[2]

Preventive Measures: To enhance or preserve bone mineral density (BMD) in postmenopausal women, it is recommended to implement lifestyle adjustments and interventions. Activities such as regular weight-bearing workouts, adequate intake of calcium and vitamin D, cessation of smoking, moderation of alcohol use, and the use of medicines, such as bisphosphonates, can be employed in specific instances.

Proper intake of calcium and vitamin D is a crucial determinant of bone health. Calcium is the primary constituent of bone tissue and plays a crucial role in the absorption of calcium. A shortage in vitamin D might result in the inability to absorb calcium. Postmenopausal women may require dietary supplements due to insufficient intake from their foods and inadequate exposure to sunlight.

Hormone Replacement Therapy (HRT): Oestrogen therapy has been extensively utilised to address a range of postmenopausal concerns, such as alleviating symptoms and preventing osteoporosis. However, due to the inherent hazards associated with its use, Hormone Replacement Therapies (HRT) have grown increasingly specialised. Therefore, while considering HRT, one's health history and preferences should be taken into account.

Frequent Monitoring: It is often advised to regularly do BMD testing to keep track of bone health and evaluate the success of therapies. The testing frequency may differ based on individual risk factors.[12]

Hence, the diversity in clinical practice might be attributed to the challenge of determining the most effective therapeutic approach. In traditional pairwise meta-analyses, studies that had different comparators were excluded because they did not meet the criteria of having randomised controlled trials (RCTs) with comparable treatment and control groups. Network meta-analysis (NMA) allows us to draw conclusions about the clinical effectiveness of all available therapy groups by combining information from both direct and indirect comparisons of different therapies.[11,13] Moreover, it has the capacity to enhance the reliability of the estimate in comparison to conventional meta-analyses. In addition, NMA can be valuable to both patients and clinicians by assessing the effectiveness of various treatments.[14]

Material and Methods

Following the guidelines laid forth by the PRISMA statement and the PRISMA network meta-analysis extension statement, this systematic review was conducted. There is a record of this review procedure in the database of registered systematic reviews and meta-analyses. Web of Science, Scopus, AMED, CINAHL, MEDLINE, EMBASE, and the Cochrane Central Register of Controlled Trials (CENTRAL) were among the electronic databases that were searched. To find further studies, we also used the search portals of the World Health Organization's International Clinical Trials Registry Platform, namely ClinicalTrials.gov and ISRCTN. There was no linguistic limitation. Additionally, in order to find any other research that may be relevant, we looked through the bibliographies of the chosen publications and the relevant review articles.[15-20]

Inclusion and Exclusion Criteria

In order to be considered for inclusion, articles needed to meet these criteria: (1) RCTs that sought to compare therapeutic exercise interventions to other forms of exercise, sham exercises, or control groups that did not exercise whatsoever, in addition to usual activity; (2) Women whose osteoporotic status was determined after menopause were eligible to participate in the study; (3) The intervention needed to last for a minimum of six months; (4) Research needed to provide either original data or sufficient information regarding one of the following outcomes: How dense the bone is, as measured by dual-energy X-ray absorption (DEXA) or dual-photon absorption (DPA) at the lumbar spine (LS), total hip (TH), or femoral neck (FN) locations. Furthermore, research that did not fit the following criteria were not considered: (1) No RCTs were conducted; (2) No clinical trials were conducted; (3) No subgroup analyses were performed; (4) Both groups used the same exercise programs; and (5) The abstracts were from conferences rather than full articles published in peer-reviewed journals; neither the abstracts nor the data were provided, even after contacting the author.[21,22]

Classification of Workouts

We classified the exercise intervention into 10 groups to compare the efficacy of various forms of physical activity. In table 1 and Figure 1 you can see what these interventions are defined as. Reviewers worked in pairs and extracted pertinent data using a pre-piloted extraction form. In the event that any disputes arose, a third arbiter was brought in. We recorded: general manuscript information (author, year of publication, region), participant demographics and clinical characteristics (number of participants, age, body mass index (BMI), years since menopause, additional supplement), intervention protocols (exercise type, frequency, duration, main part of exercise, intervention setting, session length, compliance, adverse events, and quality assessment), and outcomes (in each study). LS, TH, and FN bone mineral density (BMD) was measured immediately after surgery using DXA or DPA. The primary metric for success was the change in BMD relative to the initial values (i.e., the difference between the end-point and baseline scores). A plot digitizer program was used to extract the numerical data in order to present the results graphically. Evaluations of quality were conducted using the PEDro scale.[23,24]

Table 1: Features of Research that were Considered.

Authors	Sample Size	Age in Years	BMI (kg/m2)	Years of Menopausea	Detection of Osteoporosis or Osteoopenia was Made	Supplementary Information
ElDeeb2020	43	55.09±4.19	28.4±1.31	3 years or more	Y	Calcium and
Sen 2020	49	55.0 ± 4.6	26.6 ± 2.7	8.0 ± 4.1	Y	Calcium D and vitamin
Montgomery 2020	29	56.0 ± 3.0	25.4 ± 2.0	1 – 5 years	-	NA
de Oliveira2019	34	56.4±6.5	26.2±2.6	WBV 8.8±5.1	Y	No
Duff2016	44	65.3±4.6	-	-	-	Calcium and Vitamin D
Nicholson2015	57	66.0±4.1	26.0±3.2	5	-	-
Wang2015	83	58.54±3.37	-	1/2	-	-
Liu2015	90	63.23±7.56	-	13.79±6.27	Y	-
Moreira2014	100	58.6±6.71	-	5	Partial	Calcium and vitamin D
Lai2013	28	60.1±7.1	22.7±1.9	9.8±8.7	Y	-
Chilibeck2013	174	55.3±6.3	-	one	-	Calcium and vitamin D
Kemmler2013	83	52.3±2.3	-	2±0.7	Partial	Calcium and vitamin D
Basat2013	35	55.9±4.9	25±4.7	6±3.6	Y	Calcium and vitamin D
Orsatti2013	36	56.6±8.8	26±3	8.7±6.1	-	-
Wayne2012	86	58.8±5.6	25.8±4.2	one	Y	Calcium
Karakiriou2012	32	53.4±0.87	-	4.8±0.57	Y	-
Bolton2012	39	60.3±5.6	25.2±4.3	13±7.4	Y	Calcium and vitamin D
von Stengel2011	151	68.6±3	26.2±4.2	-	-	Calcium and vitamin D
von	34	68.1±4	26.9±4.12	-	-	Calcium and vitamin D
Stengel2011(1)	63	67.9±3.8	27.2±4.26			
Tartibian2011	38	61.4±6.9	25.1±7.1	8	-	-
Slatkovska2011	224	60.5±7	24.9±4	8.6±6	Y	-
Marques2011	71	67.3±5.2	28.8±4.6	-	Y	-
Marques2011(1)	60	70.1±5.4	28.4±3.7	-	Y	-
Sakai2010	49	68.3±0.8	22.4±0.4	-	-	-
Kemmler2010	57	68.2±0.5	22.6±0.4	-	Partial	calcium and vitamin D
Beck2010	42	68.9±7	26.7±4.4	5	Y	-
Bebenek2010	85	52.3±2.3	-	3	-	calcium and vitamin D
Chuin2009	18	65.4±3.5	26.54±2.74	-	-	-
Bocalini2009	25	69±9	28±4	-	-	-
Park2008	50	68.3±3.6	-	18.3±2.5	-	-
Bergstrom2008	48	58.9±4.3	24.4±2.6	-	Y	Calcium and vitamin
Young2007	54	59.6±3.6	24.9±2.3	16.1±7.7	-	DCalcium
Woo2007	30	69.67±2.8	24.4±4.3	-	-	-
Maddalozzo2007	29	52.3±3.3	19–30	2.1±0.8	-	-
Evans2007	21	62±5.3	-	6.6±5.9	-	soy protein isolate,
Wu2006	53	63.1±5	22.4±2.9	8.3±5	-	milk protein isolate
Korpelainen2006	84	72.9±1.1	25.7±3.4	-	Y	-
Gusi2006	14	66±6	-	5	-	-
Englund2005	21	72.8±3.6	25.2±2.7	-	-	-
Verschueren2004	25	64.6±3.3	26.34±3.6	16.9±6.3	-	-
Liu-Ambrose2004	32	79.6±2.1	-	29.8±5	Y	-
Chan2004	132	54.4±3.3	24.1±4.7	4.9±2.5	-	-
Milliken2003	52	40–65	-	7	-	Ca citrate
Jessup2003	18	69.1±2.8	-	23.7±11.3	-	Ca2+ and vitaminD
Going2003	52	55.3±4.4	25.6±3.8	7	-	Ca citrate
Hans2002	131	67.6±5.2	-	5	Y	Calcium and vitamin D
Chilibeck2002	22	56.8±2	27±1.7	8.6±2.2	Y	Calcium and vitamin D
Kerr2001	126	60±5	-	11±6	-	Calcium
Iwamoto2001	28	65.3±4.7	19.7±1.3	16.3±5.9	Y	Calcium and vitamin D

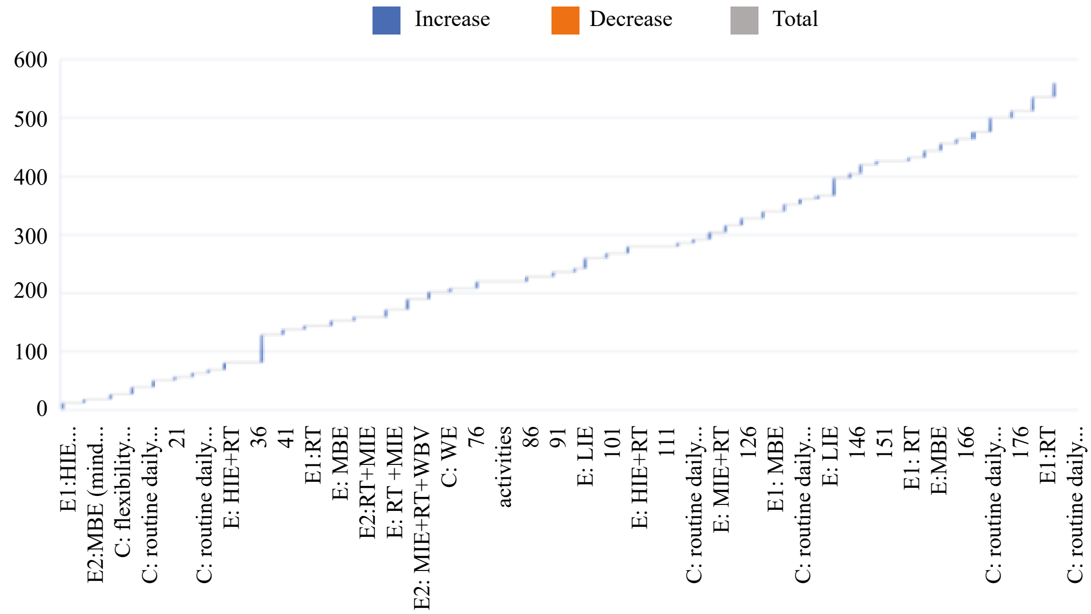

Figure 1: Features of Research that were Considered.

Analysis of Data and Synthesis of Data

We calculated the effect size (ES) by averaging the change scores. We used random-effects models to combine the effect sizes from different research as the results of previous systematic reviews were inconsistent. We used STATA V16.0 to do a meta-analysis for all available direct comparisons. To assess statistical heterogeneity, we computed an I2 value and ran the Q test. To determine whether heterogeneity was moderate or high, we looked for I2 values over 25% and 50%, respectively. We used Stata 16's network plots to learn more about the interrelationships and relative merits of different workout routines. Also, to check for publication bias caused by little studies, a network funnel plot was made when there were 10 or more trials for one comparison.

In GeMTC 0·14·3, which stands for «Generate Mixed Treatment Comparisons,» network analysis was carried out. Using a Bayesian Markov chain Monte Carlo approach, we determined mean differences and associated 95% credible intervals (CrIs) for BMD at LS, FN, and TH, and we made sure that all direct and indirect evidence was consistent when comparing exercise programs. The following steps were taken to implement GeMTC: the starting values were scaled to 2.5, a lengthy burn-in and follow-up time was permitted with a thinning interval of 10, and convergence was achieved. A total of four chains were established. After comparing the therapies' effectiveness, they were rated in order of preference. The probability of being the best (PrBest) intervention was omitted in favor of surface under cumulative ranking (SUCRA), which is considered a more accurate way for computing ranking probabilities. If the SUCRA number is 1, then the exercise intervention ranks first; if it's 0, then it ranks last.

Confidence in Proof

The reliability of the NMA's findings was evaluated using Confidence in Network Meta-Analysis (CINeMA). Evidence was evaluated by two separate researchers for incoherence, heterogeneity, indirectness, imprecision, and reporting bias as well as within-study bias. To demonstrate how strong the NMA recommendations are, we graded the evidence from the NMA overall.

Results

After sifting through 29,86 records based on titles and abstracts, we were able to add 50 trials with 3,673 participants in our network meta-analysis after they matched all of the inclusion criteria. Tables 2 Figure 2 and Table 3 and Figure 3 display the baseline participant characteristics and exercise protocols of all the studies that were considered. With a mean age range of 51.92 to 80.76 years, the sample size varied from 16 to 239 people. The United States accounted for thirteen randomized controlled trials, whereas Australia had seven and Canada had six. The average number of years till menopause was at least 0.66 and may vary from 29.43, whereas the average BMI was between 19.66 and 28.92 kg/m2. Either the house or the center might be used to offer the exercise intervention. About 40% to 95% of participants really completed the workout. The included studies' PEDro scores were 5·38, with a range of 3 to 7. Ten studies (20%) have excellent quality, thirty-three (66%) have moderate quality, and seven (14%). There was good convergence across all models. All results have parameter PSRF values close to 1, which means that convergence is going well. When comparing the comparison groups for all outcomes, discrepancy between direct and indirect estimates from the node splitting analysis did not reveal any significant differences.

Table 2: Study Features Regarding Exercise Prescriptions.

Author	Exercise Category	Time Period	Number	Central Component of the Fitness Program	Setting Intervention	Minimal Amount of Time Spent in Session	Meeting All Requirements	Unwanted Consequences
ElDeeb 2020	ordinary, regular, everyday existence	7	3	Magnitude 2-4 millimeters	monitored, center-based	5-10	NA	NA
Sen 2020	ordinary, regular, everyday existence	7	4	Muscles in the legs and back and each session, jump rope anything from ten to sixty times.	Center-based, supervised	20-60	E1: 84.1% E2: 81.3%	No
Montgomery 2020	ordinary, regular, everyday existence	11	2	thirty concussions per minute with a stimulation frequency of fifteen per minute	home-based, unsupervised	8	E1: 60% E2: 68.5%	No
de Oliveira 2019	ordinary, regular, everyday existence	7	2	Pilates with an emphasis on Borg-style intensity for all major muscle groups	Center-based, supervised	55	93%	-
Duff 2016	E: RT C: flexibility exercise	8	4	Three sets of full-body flexibility exercises lasting 18–25 seconds each	Center-based, supervised	NA	E: 84% C: 87%	No
Wang 2015	ordinary, regular, everyday existence	11	3	Resistance training for Tai Chi Simplified	Center/home-based, partially supervised	E1: 60 E2: 60	NA	No
Liu 2015	ordinary, regular, everyday existence	11	4	Updated section six Brocade, two times a day, five repetitions each	home-based, supervised	NA	E:96%	No
Nicholson 2015	ordinary, regular, everyday existence	7	3	With few weights and a high rep count, do squats, lunges, and chest presses.	Center-based, supervised	48	90%	No
Moreira 2014	ordinary, regular, everyday existence	7	2	Resistance training in water at 50% to 85% of one's maximum heart rate	monitored, center-based	50-60	E:85%	No
Lai2013	ordinary, regular, everyday existence	7	2	The horizontal, magnitude 3.2 g, and frequency 30 Hz	monitored, center-based	5	E:88%	No
Kemmler 2013	ordinary, regular, everyday existence	11	2	Five to sixteen sets of varying multilateral leaps were performed	Center-based, supervised	45-60	E: 67% C: 70%	No
Chilibeck 2013	ordinary, regular, everyday existence	50	4	activities that stretch all of the main muscle groups	monitored, center-based	20-30	E:77%	No
Orsatti 2013	ordinary, regular, everyday existence	10	4	the main muscle groups should be worked in three sets of eight to twelve repetitions at sixty percent to eighty percent of one resting mass.	Center-based, supervised	50-60	NA	No
Basat 2013	ordinary, regular, everyday existence	5	2	ten-repetition workout for the back and lower body	monitored, center-based	55	55%	-
Wayne 2012	ordinary, regular, everyday existence	10	3	5-repetition workout for the back and lower body	Center/home-based, partially supervised	30-60	NA	No
Karakiriou 2012	ordinary, regular, everyday existence	7	2	In order to strengthen every major muscle group, we performed 3-4 sets of 9–11 repetitions at 68% of our 1RM.	Center-based, supervised	11	80%	-
Bolton 2012	ordinary, regular, everyday existence	15	2	increase the number of jumps to ten three times a day	Center/home-based, partially supervised	60	E:88%	NA
Von Stenge l2011	ordinary, regular, everyday existence	21	3	Gracefully moving between 70 and 80% of one's heart rate maximum	monitored, center-based	20-60	E1:75% E2:80%	No
Von Stenge l2011(1)	ordinary, regular, everyday existence	9	2	gentle physical activity	monitored, center-based	16	72%	No
Tartibian 2011	ordinary, regular, everyday existence	5	4	achieving a heart rate maximum of 50–70% when walking on a treadmill	monitored, center-based	25-45	>95%	NA
Slatkovska 2011	ordinary, regular, everyday existence	9	7	30 hertz, magnitude 0.3 g	Home-based, supervised	20	E1:79% E2:77%	Dizziness(0,1,0) pain, numbness, or weakness innerear sensitivity (1,0,0) bladderdiscomfort (1,0,0)
Marques 2011	ordinary, regular, everyday existence	6	4	aerobics, dancing, stepping, skipping, running, aerobics at 50-85% of one's maximum heart rate, and other similar activities	Center-based, supervised	60	E1:77.7% E2:78.4%	No
Marques 2011(1)	ordinary, regular, everyday existence	6	3	walking with a dropped heel LIRT consists of squats with weighted vests, workouts targeting the hips, knees, and abductors, and upper body movements with bands and weights.	Center-based, supervised	60	E: 72.4%	No
Sakai 2010	ordinary, regular, everyday existence	5	4	This exercise was performed in three sets of one-leg standing, with each leg being used for one minute each.	Home-based, unsupervised	6	70%	NA
Kemmler 2010	ordinary, regular, everyday existence	21	3	gentle physical activity	Center/home-based, partially supervised	20-60	E:76.3% C:72%	No
Beck 2010	ordinary, regular, everyday existence	6	3	gentle physical activity	monitored, center-based	E2: 4	E2:91%	No
Bebenek 2010	ordinary, regular, everyday existence	9	4	A set of eight to twelve functional gymnastics exercises targeting the muscles of the trunk and lower extremities	Center-based, supervised	60	65%	No
Chuin 2009	ordinary, regular, everyday existence	5	4	Full-body exercises including two sets of nine repetitions at 75% of one's maximum power	Center- based, supervised	60	NA	NA
Bocalini 2009	ordinary, regular, everyday existence	5	4	Full-body exercises including two sets of nine repetitions at 70% of one's maximum power	Center-based, supervised	60	NA	-
Park 2008	ordinary, regular, everyday existence	9	4	Resistance training with a heart rate between 70 and 80% of maximal value	-	55	-	-
Bergstrom 2008	ordinary, regular, everyday existence	9	3	Muscular strengthening routines for the torso, limbs, and abdominals	monitored, center-based	60	95%	NA
Young 2007	ordinary, regular, everyday existence	9	3	two sets of eight reps of squatting, with weights increased by two kg per set	Home-based, unsupervised	50	79%	-
Woo 2007	ordinary, regular, everyday existence	9	2	For both the upper and lower body, medium-strength exercises were used.	Center-based, supervised	NA	E1:81% E2:76%	NA
Maddalozzo 2007	ordinary, regular, everyday existence	9	3	three rounds of back squats and deadlifts at 65-80% of one rep maximum	Center-based, supervised	50	84.7%	No
Evans 2007	ordinary, regular, everyday existence	9	3	at an intensity ranging from 55% to 80% of VO2peak on a four-lane, seventeen-lap per mile indoor track, as well as on rowing and stair-climbing ergometers.	Center-based,	45	NA	NA
Wu 2006	ordinary, regular, everyday existence	5	2	moving at a pace of four to five kilometers per hour	monitored, center-based	60	NA	NA
Korpelainen 2006	ordinary, regular, everyday existence	28	6	dancing, stomping, stair climbing, bending knees, lifting legs, stepping on and off benches,	home-based supervised ,	60	75%	NA
Gusi 2006	ordinary, regular, everyday existence	6	4	walking	Center-based, supervised	E:30 C:60	78%	No
Englund 2005	ordinary, regular, everyday existence	12	3	running, stepping in various patterns and orientations	Center-based, supervised	50	67%	No
Verschueren 2004	ordinary, regular, everyday existence	5	4	Complete three sets of seven to seventeen repetitions per muscle group in the lower body.	NA	E1:30 E2:60	NA	No
Liu-Ambrose 2004	ordinary, regular, everyday existence	5	3	3 sets of 5–13 reps at 45-75% of your maximum rep range for each of your main muscle groups	Center-based, supervised	50	E1:84% E2:87% C:79%	sore neck, muscle soreness (10,4,1)
Chan 2004	ordinary, regular, everyday existence	9	6	jumping, skipping	monitored, center-based	50	84%	Fracture(1,3)
Milliken 2003	ordinary, regular, everyday existence	9	4	Get every major muscle group to do three sets of seven to ten repetitions at 65% to 75% of one repetition maximum.	Center-based, supervised	75	NA	NA
Jessup 2003	ordinary, regular, everyday existence	12	4	climbing up and down stairs while wearing a safety vest	Center-based, supervised	60-90	NA	NA
Going 2003	ordinary, regular, everyday existence	9	4	Using weighted vests for skipping, hopping, and stair climbing/step boxes.	monitored, center-based	-	79.9%	-
Hans 2002	ordinary, regular, everyday existence	18	7	on a platform that measures forces while barefoot	home-based, unsupervised	3-5	65%	No
Chilibeck 2002	ordinary, regular, everyday existence	9	2	Sets of 10–12 reps at 75% of one repetition maximum throughout all main muscle groups	Center-based, supervised	NA	77.6%	NA
Kerr 2001	ordinary, regular, everyday existence	18	2	the same resistance training with a reduced and constant load	Center-based, supervised	55	75%	A wrist injury
Iwamoto 2001	ordinary, regular, everyday existence	18	3	gymnastics training, which includes 15 sets of exercises to develop the abdomen and back muscles as well as the leg muscles, and squatting.	home-based,	NA	NA	NA

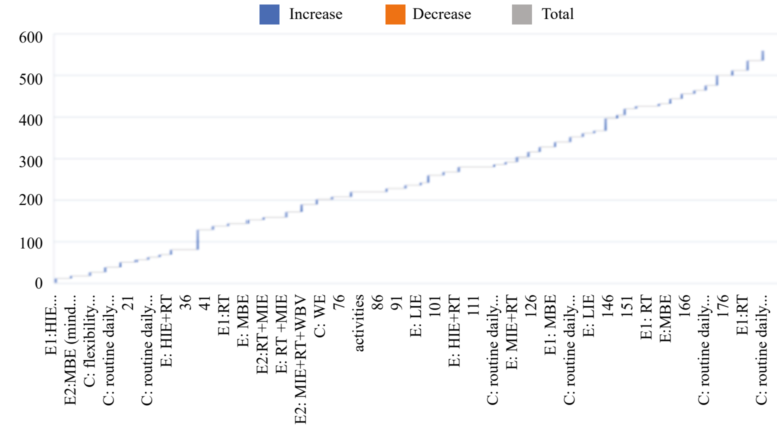

Figure 2: Table 2 Study Features Regarding Exercise Prescriptions.

Table 3: Comparisons of BMD at LS between the Various Treatments and the Control Group, with Respect to their Relative Effects.

Control	**-.03 (-.04,-.02)**	**-.02 (-.02,-.01)**	.01 (-.02,.02)	-.02 (-.04,.01)	**-.02 (-.03,-.01)**	-.03 (-.06,.01)	-.00 (-.02,.01)	-.00 (-.01,.01)	**-.00 (-.01,-.01)**	-.00 (-.05,.02)
-.02 (-.03,-0.01)	RT	.00 (-.01,.01)	**.03 (.01,.04)**	.01 (-.03,.03)	.02 (-.02,.03)	-.03 (-.05,.03)	.01 (-.00,.01)	.00 (-.00,.01)	.00 (-.02,.03)	.01 (-.03,.03)
-.02 (-.03,-0.02)	-.01 (-.02,.02)	ME	**.03 (.02,.04)**	.01 (-.03,.03)	.01 (-.01,.02)	-.01 (-.05,.01)	.01 (-.02,.03)	.00 (-.00,.01)	.02 (-.02,.03)	.01 (-.03,.03)
.01 (-.02,.02)	**.02 (.01,.03)**	**.02 (.01,.02)**	WE	-.03 (-.04,.01)	**-.02 (-.03,-.01)**	-.03 (-.06,.01)	-.00 (-.02,.02)	-.02 (-.04,.01)	-.00 (-.01,.01)	-.01 (-.07,.02)
-.02 (-.04,0.01)	-.01 (-.03,.02)	.00 (-.01,.01)	-.02 (-.04,.01)	FE	.02 (-.02,.03)	-0.1 (-.07,.03)	.01 (-.03,.02)	.02 (-.02,.04)	.01 (-.02,.03)	.01 (-.03,.04)
-.02 (-.02,-.01)	.01 (-.02,.02)	.00 (-.00,.01)	**-.02 (-.03,-.01)**	.01 (-.02,.03)	WBV	-.04 (-.07,.02)	-.01 (-.01,.01)	.01 (-.02,.00)	-.01 (-.00,.02)	-.01 (-.04,.03)
-.04 (-.08,-.01)	-.04 (-.07,.02)	-.02 (-.06,.01)	**-.03 (-.06,-.01)**	-.03 (-.07,.03)	-.04 (-.07,.02)	HIE	.03 (-.03,.07)	.02 (-.00,.07)	.02 (-.00,.07)	.01 (-.03,.07)
-.02 (-.03,.02)	.01 (-.02,.03)	.01 (-.00,.02)	-.02 (-.03,.02)	.02 (-.02,.04)	.01 (-.02,.03)	.04 (-.02,.06)	MIE	.01 (-.01,.01)	.01 (-.01,.01)	-.01 (-.04,.03)
-.02 (-.03,-.01)	-.01 (-.02,.02)	.00 (-.01,.02)	-.02 (-.03,.01)	.01 (-.02,.03)	-.01 (-.02,.02)	.02 (-.00,.07)	-.01 (-.03,.00)	LIE	-.01 (-.01,.01)	-.00 (-.04,.03)
-.02 (-.03,-.02)	.01 (-.02,.02)	.00 (-.01,.01)	-.02 (-.03,.01)	.01 (-.02,.03)	.01 (-.02,.02)	.02 (-.00,.07)	-.01 (-.03,.02)	.01 (-.00,.00)	MBE	-.01 (-.03,.03)
-.03 (-.07,.04)	-.01 (-.05,.03)	-.00 (-.04,.04)	-.03 (-.07,.04)	-.01 (-.05,.03)	-.02 (-.05,.03)	.01 (-.02,.06)	-.00 (-.05,.03)	-.01 (-.05,.03)	-.00 (-.05,.03)	WBE

The following factors were associated with improvements in BMD at LS: multicomponent exercise (0·01 g/cm2), resistance training (0·01 g/cm2), mind-body exercise (0·01 g/cm2), lower impact exercise (0·01 g/cm2), high impact exercise (0·02 g/cm2), and whole body vibration (0·01 g/cm2), all with 95% CrI values ranging from 0·00 to 0·03. No longer was there a link between high-impact or low-impact exercise and enhanced BMD as compared to control when 7 low-quality studies were eliminated (23–35; see table 4 and Figure 3).

Table 4: Assessments of the Relative Effects of the Various Therapies and Controls on Bone Mineral Density (BMD) at FN.

Control	-.00 (-.01,.01)	**-.02 (-.04,-.01)**	-.01 (-.03,.01)	-.00 (-.03,.02)	**-.02 (-.03,-.00)**	-.01 (-.03,.03)	.01 (-.01,.01)	-.00 (-.01,.02)	**-.03 (-.02,-.01)**	-.01 (-.06,.01)
-.00 (-.01,.01)	RT	**-.01 (-.03,-.01)**	-.00 (-.02,.01)	-.01 (-.04,.03)	-.00 (-.02,.02)	.02 (-.03,.04)	.00 (-.02,.03)	.01 (-.01,.01)	-.00 (-.02,.02)	-.00 (-.07,.02)
-.02 (-.03,-.01)	**-.01 (-.02,-.01)**	ME	.00 (-.00,.03)	.01 (-.01,.03)	.00 (-.01,.04)	.02 (-.02,.06)	**.03 (.00,.07)**	**.04 (.02,.04)**	.01 (-.00,.03)	.00 (-.02,.04)
-.01 (-.03,.02)	-.01 (-.01,0.03)	.01 (-.01,.03)	WE	.01 (-.03,.03)	-.01 (-.03,.01)	.01 (-.02,.07)	.01 (-.02,.04)	.02 (-.00,.03)	.01 (-.02,.02)	.00 (-.03,.01)
-.00 (-.02,.02)	-.01 (-.01,.01)	.01 (-.00,.03)	-.01 (-.02,.02)	FE	-.01 (-.02,.01)	.02 (-.02,.07)	.01 (-.00,.04)	.00 (-.01,.02)	-.01 (-.02,.01)	-.00 (-.07,.03)
-.03 (-.02,-.01)	-.00 (-.02,0.02)	.02 (-.02,.04)	-.00 (-.02,.02)	-.02 (-.02,.01)	WBV	.01 (-.02, .07)	.01 (-0.01, 0.04)	.00 (-.00, .02)	.01 (-.01, .01)	-.02 (-.04, .03)
-.01 (-.03,.03)	.01 (-.03,.04)	.01 (-.01,.07)	.00 (-.03,.04)	.00 (-.03,.04)	.00 (-.02,.07)	HIE	.00 (-.03, .04)	-.00 (-.04, .03)	-.01 (-.07, .02)	-.01 (-.07, .03)
.01 (-.00,.03)	.00 (-.00,.02)	**.04 (.02,.06)**	.00 (-.02,.04)	0.00 (-.00,.02)	.13 (-.01,.03)	.00 (-.03,.04)	MIE	-.00 (-.03, .00)	-.01 (-.04, .02)	-.02 (-.06, .01)
-.00 (-.01,.00)	-.01 (-.03,.03)	.01 (-.01,.03)	.01 (-.01,.01)	.01 (-.01,.02)	.02 (-.02,.04)	-.00 (-.04,.03)	-.00 (-.02,.02)	LIE	-.00 (-0.04, .02)	-.01 (-.07, .02)
-.03 (-.04,-.01)	-.00 (-.02,.02)	.02 (-.02,.04)	-.02 (-.04,.01)	-.00 (-.02,.01)	-.01 (-.01,.01)	-.00 (-.07,.02)	-.01 (-.03,.01)	-.00 (-.02,.02)	MBE	-.00 (-.03, .02)
-.01 (-.07,.01)	-.01 (-.07,.02)	.01 (-.03,.03)	-.00 (-.07,.02)	-.00 (-.07,.02)	-.02 (-.04,.03)	-.01 (-.07,.03)	-.02 (-.06,.01)	-.01 (-.07,.04)	-.00 (-.04,.03)	WBE

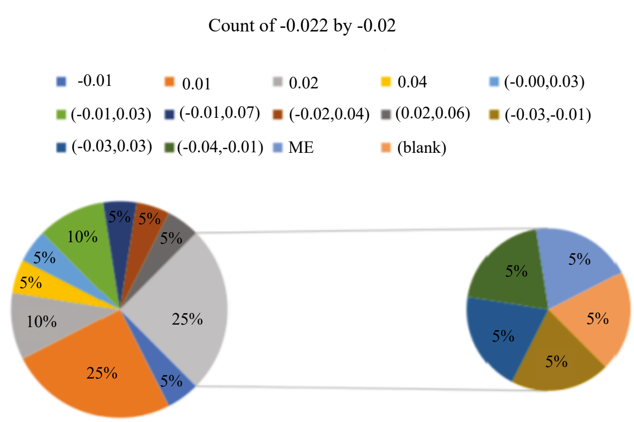

Figure 3: Assessments of the Relative Effects of the Various Therapies and Controls on Bone Mineral Density (BMD) at FN.

From the high-quality studies that were included, high-impact exercise was likely the most effective exercise intervention, compared to strength training (SUCRA = 0.69) and multicomponent exercise (SUCRA = 0.64). The results were constrained by the small sample size (three trials) and the large 95% confidence intervals (CrIs). Following a thorough evaluation of all research, high impact exercise (0·89) emerged as the most effective exercise intervention, followed by multicomponent exercise (0·69) and flexibility exercise (0·59). Multicomponent exercise (0·03 g/cm2, 95% CrI 0·00 to 0·03), whole body vibration (0·02 g/cm2, 95% CrI 0·00 to 0·04), and mind body exercise (0·02 g/cm2, 95% CrI 0·00 to 0·04) were the only three forms of exercise shown to effectively enhance bone mineral density (BMD) at FN. Comparing multicomponent exercise to weight training and low impact exercise also revealed significant benefits. There was an increase in the effect size of multicomponent exercise compared to lower impact exercise from 0.02 g/cm2 to 0.04 g/cm2, with a 95% confidence interval (CrI) of 0.01 to 0.06 (table 5), after nine studies of poor quality were removed.[24-37]

Out of all the exercise interventions evaluated in high-quality research, multicomponent exercise had the highest chance of being the best option, followed by water-based exercise (0.71) and whole-body vibration (0.59). Incorporating all trials into the SUCRA and rankogram plots resulted in a same pattern. Strength training (0·01 g/cm2, 95% CrI 0·00 to 0·03), flexibility exercise (0·01 g/cm2, 95% CrI 0·00 to 0·03), and multicomponent exercise (0·01 g/cm2, 95% CrI 0·00 to 0.02) were the only methods that improved BMD at TH. Flexibility and strength training activities had far better results than full-body vibration. Compared to whole-body vibration, multicomponent exercise was associated with higher bone mineral density (BMD) at TH, and this finding persisted after excluding two trials with poor quality. Among the exercise interventions tested in high-quality research, resistance training had a higher chance of being the most successful than either flexibility exercise or multicomponent exercise (0.86% vs. 0.79% and 0.69%, respectively). Incorporating all trials into the SUCRA and rankogram plots resulted in a same pattern. At LS, whole-body vibration, lower-impact activities, strength training, and multicomponent exercise resulted in the highest increase in bone mineral density (BMD) for those aged 59 and above. In terms of bone mineral density (BMD), multicomponent exercise was more effective than control, moderate impact activity, and strength training at FN. Bone mineral density (BMD) at TH was not enhanced by exercise in patients aged 59 and above. Weight training, mind-body activities, multicomponent exercises, and high-impact exercise all increased bone mineral density (BMD) in LS participants younger than 59 years old. In terms of bone mineral density (BMD), the mind-body, multi-component, and flexibility exercise groups did better than the control group at FN. At TH, exercise had no appreciable effect on BMD in those younger than 59 years old. For exercise programs that lasted less than eight months, LS found that whole-body vibration, mind-based exercise, weight training, and multicomponent exercise all contributed to better bone mineral density (BMD). At FN, a multicomponent exercise program improved bone mineral density (BMD) more than a control group, a moderate-impact exercise program, a strength training program, and a flexibility program. There was no effect of exercise on TH bone mineral density (BMD) when the intervention duration was less than eight months. Over the course of 8–17 months, exercise programs that included resistance training, high-impact workouts, flexibility exercises, and multicomponent workouts significantly improved bone mineral density (BMD) at LS. At FN, the control group had lower bone mineral density (BMD) than the mind-body exercise group, but at TH, weight training considerably raised BMD.

Due to a lack of evidence, no subgroup analyses could be carried out for BMD at LS, FN, and TH with intervention durations beyond 18 months. After adjusting for comparisons, the funnel plots were visually examined. There was no clear indication of publication bias for BMD at LS and FN, with the exception of TH (Figure 4).

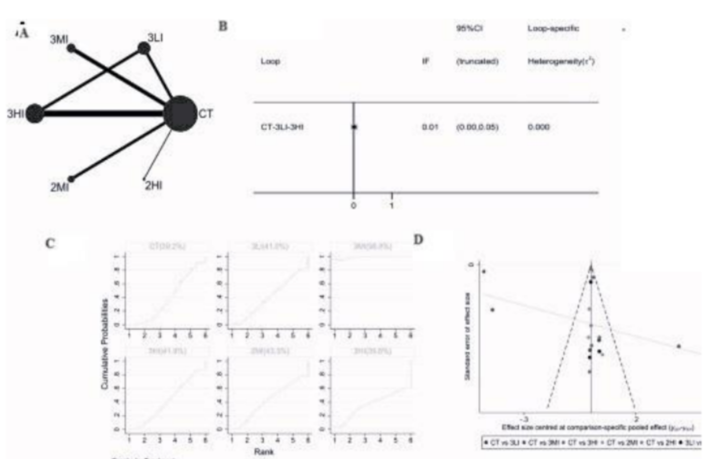

Figure 4: Forest Plot.

Triangles on the bottom left represent summary estimates from the network meta-analysis, while triangles on the top right show summary estimates after low-quality studies are excluded. The MD and 95% CI are shown in parentheses for each cell. A positive SMD favors the upper-left intervention for any given cell, whereas a negative MD favors the lower-right intervention. Bold results indicate significant findings.

Triangles on the bottom left represent summary estimates from the network meta-analysis, while triangles on the top right show summary estimates after low-quality studies are excluded. The MD and 95% CI are shown in parentheses for each cell. A positive SMD favors the upper-left intervention for any given cell, whereas a negative MD favors the lower-right intervention. Results that are significant are bolded.

Discussion

This NMA examines the impact of several fitness programmes on bone mineral density (BMD) in postmenopausal women and compares their effects. Caution should be exercised when interpreting the results due to the low to extremely low quality of evidence as determined by the CINeMA criteria. The findings indicate that the most successful therapies for improving bone mineral density (BMD) at lower density (LS) and functional neuron (FN) are multicomponent exercise and resistance training (2)

The large range of exercise programmes and the diverse features of participants may partially account for the poor effectiveness of exercise interventions, despite their endorsement in several global recommendations. Our findings align with previous meta-analyses and comprehensive reviews, indicating that combining impact exercise with resistance training or adjusting the intensity of impact exercise might successfully mitigate bone density loss in the lumbar spine (LS) and femoral neck (FN).[28-31] Strength training typically yields a larger effect size compared to impact and multicomponent workouts, which aligns with the conclusions drawn by Kemmler.[9,32,33]

Consequently, single component training programmes typically have localised effects on bone. Exercise intensity, frequency of stimulation, and pattern of mechanical loading are all crucial factors for enhancing skeletal response. It has been shown that dynamic mechanical stimulation is necessary for adaptive skeletal response, rather than static stimulation.[34] Hence, the most optimal choice for improving bone health post-menopause may be a multicomponent fitness regimen that encompasses all the essential components. This phenomenon could elucidate the reason why multi-component exercise has the capacity to augment all results, albeit to varying extents. Our age-based subgroup analysis reveals significant trends when compared to the findings of prior literature. The inconsistent findings may be attributed to the different inclusion criteria of the research, such as controlled trials, language, and the use of additional calcium and vitamin D supplements. Elderly women still have a positive response to exercise, which can be partially attributed to the enhanced absorption of calcium that happens as a result of exercise, as well as the beneficial effects of mechanical stimulation on bone health.[35]

When strain was consistently increased, it is anticipated that longer periods of intervention will result in greater benefits for the bones. Determining the exact amount of new mineral bone from treatments lasting less than 8 months can be challenging if we accept the notion that exercise-induced increases in bone mineral density (BMD) are mostly caused by remodelling and take into account the duration of an adult's remodelling cycle. However, subgroup analysis revealed that certain training routines had a considerably stronger effect on bone mineral density (BMD) at the lumbar spine (LS) and femoral neck (FN) in trials of shorter duration compared to studies of longer duration. Participants at LS and FN experienced a more significant effect from a multicomponent workout. We determined that the complex interaction of exercise parameters was accountable for this concerning finding. This study evaluates and contrasts the impacts of different exercise routines on bone mineral density (BMD) in women who have had menopause, making it the pioneering research of its kind. To identify acceptable research without any language limitations, a thorough search of multiple databases and sources was necessary. Two independent reviewers conducted the whole literature search, data extraction, and methodological quality assessment to assure precision and minimise bias.

Nevertheless, it is crucial to acknowledge many notable deficiencies in this network meta-analysis. A significant limitation arises from our reliance not solely on the authors' descriptions of the exercise and control groups for their classification. Both the exercise intervention and the group settings exhibit a high degree of variability and are rarely standardised. We categorised the exercise intervention based on the article's description and our exercise criteria. Despite the implementation of strict inclusion criteria to assure comparability of treatments across trials, the included treatments nevertheless encompassed a variety of exercise regimens. The findings suggest that a comprehensive examination of the specific physical elements comprising an effective combination intervention is necessary. Furthermore, despite our attempts to contact the pertinent authors, there is still a lack of specific outcome data. Therefore, some standard deviations of the absolute change in BMD were calculated using a specific formula, which could potentially affect the accuracy of the results. Research examining the influence of physical activity on bone mineral density at the hip has also uncovered substantial evidence of biassed reporting. The actual influence of exercise on bone mineral density (BMD) can be slightly lower than the numbers presented in this context, as authors tend to choose cite positive results. In addition, although the alteration in bone mineral density (BMD) is the primary outcome of our study, it accounts for approximately 60% of the variability in bone strength. We excluded further surrogate characteristics, such as microarchitecture. Furthermore, the interpretation of the data can be subject to criticism as it solely relied on the impact sizes observed at the end of the intervention, without considering those observed throughout future follow-up periods. However, we argue that, like medicine, exercise interventions are most beneficial during the implementation period. Therefore, the effect sizes following the intervention were the most significant ones. When comparing the Cochrane Risk of Bias 2 tool to the PEDro scale, which evaluates methodological quality, it is possible that the PEDro scale may underestimate the risk of bias in the studies that are included.[36] Furthermore, the treatment estimates may be subject to change when fresh high-quality data is obtained, due to the frequently limited quality of evidence.

Conclusion

The NMA indicates that exercise treatment significantly enhances bone mineral density in postmenopausal patients. Furthermore, it illustrates that the magnitude of the influence varies depending on the duration of the intervention, the age of the participants, and the specific outcome being studied. Clinicians may refer to the study's graded exercise interventions to choose the most effective personalised exercise routine for increasing bone mineral density (BMD).

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