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RESEARCH ARTICLE

A feasibility study of training in a local community aimed upon health promotion with special emphasis on musculoskeletal health effects [version 1; peer review: 2 not approved]

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Abstract

Background: To minimize fracture risk, multimodal training regimens are recommended. However, their effectiveness in community settings remains uncertain. This study evaluated the feasibility of 19-weeks of multimodal training in a local community center with emphasis on musculoskeletal health in postmenopausal women.

Methods: In a controlled trial, 28 postmenopausal women (53-68-years-old) were assigned to a multimodal training group (MMT, n=15) or a control group (CON, n=13). The training consisted of high- and odd-impact, resistance and balance-coordination training 1-2 hours weekly. The outcomes were attendance rate, regional and total bone mineral density (BMD), bone mineral content (BMC), bone turnover markers (BTM), body composition, functional muscle strength and power, and dynamic balance. All were determined at baseline and after 19 weeks of training. BTM was assessed after three weeks.

Results: Overall, 22(79%) participants (MMT, n=9; CON, n=13) completed the study, and the mean attendance rate for MMT was 65.5% of the maximum sessions (2) offered. Only right trochanter BMD increased ($p<0.05$) by $1.0\pm1.1\%$ in MMT, which was higher($p<0.05$) than CON. While whole-body BMC was not changed at 19 weeks from baseline in MMT, it decreased ($p<0.05$) in CON resulting in a significant difference ($p<0.05$) in whole-body BMC delta values between the two groups. Compared to baseline, body fat

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percentage(%BF), fat mass(FM), and visceral adipose tissue (VAT)-mass and -volume were decreased ($p<0.01$) in MMT, and were larger ($p<0.05$) than CON. No significant changes were observed in BTM, muscle strength and power, and dynamic balance after 19 weeks.

Conclusions: Nineteen weeks of multimodal training 1-2 hours per week in a local community had a health-enhancing effect on %BF, FM, and VAT, whereas the musculoskeletal health impact was modest. We hypothesize that the reason might be too low training volume and frequency and supposedly too low musculoskeletal training intensity for some participants.

Registration: ClinicalTrials.gov NCT05164679 (21/12/2021).

Keywords

bone mineral density, bone turnover marker, osteoporosis, high-impact, odd-impact, resistance exercise, balance training, multimodal training

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Introduction

Osteoporosis is a growing public health concern. The disease is characterized by impaired bone strength due to the reduction of bone mass and impairment of the micro-architecture of the bone, which increase the risk of bone fracture.¹ It is estimated that 200 million females are affected worldwide and causes more than 8.9 million fractures per year.² Falls in osteoporotic patients are linked to high morbidity and mortality.³ Therefore, fall prevention strategies while improving the bone strength aimed at the high-risk population are needed.⁴

One way to prevent osteoporosis can be through engaging in evidence-based training to improve bone mineral density (BMD) and reduce age-related bone loss,⁵ such as high-impact and resistance training. Furthermore, balance and coordination training can minimize the risk of falls and fractures, which is relevant to the high-risk population.⁴ Studies have shown that high-impact exercises, which produce high vertical ground reaction forces with a high force development rate,⁶ are beneficial for bone structure and mineralization in children,⁷ adults,⁸ and the elderly.⁹ In a previous study of the acute osteogenic response to high-impact jumping in postmenopausal women,¹⁰ stimulation of bone formation without any increase in bone resorption after jumping was reported. Moreover, the latter study showed a dose-response relationship between vertical as well as combined three-axes ground reaction forces (GRF) and the acute procollagen type I amino-terminal propeptide (PINP)-response after countermovement jumps.

In addition, resistance exercise, which induces various muscle loads applied to the bone,¹¹ is reported to be a relevant osteogenic training modality for maintaining or increasing bone density and mass in older people.¹² Besides, to prevent falls, balance and coordination exercises are crucial to be included as they improve static and dynamic balance.¹³ Therefore, it is hypothesized in the present study that evidence-based multimodal training as health promotion will have an osteogenic effect on bone mass and bone strength that may counteract the normal age-related bone loss in postmenopausal women and improve the dynamic balance as well as muscle strength and power, which may prevent falls and reduce the fracture risk.

Although the association between exercise training, bone loss, and falls prevention in older adults appear to be established in intervention studies,¹⁴ only a few studies have examined the effects of combined training on musculoskeletal health in postmenopausal women,^{15–17} and the results are varied. Therefore, there is still a need for safe, reliable, affordable, and evidence-based training programs that can be introduced, embraced, and sustained in high-risk populations, such as postmenopausal women.

The present study was performed in a local community setting. The aim was to investigate the feasibility and the health-promoting musculoskeletal effects of 19wk multimodal training (high- and odd-impact, resistance, balance, and coordination training) for postmenopausal women. The primary outcomes were bone mass and BTM, while body composition, dynamic balance, muscle strength and power were the secondary outcomes.

Methods

Study design

The multimodal training was offered to postmenopausal healthy women in a local community. The outcomes for the training group (MMT) were compared with a sedentary control group (CON). Training was offered twice weekly for one hour, and the average attendance rate of MMT participants over the 19wk had to be > 1 hour weekly. To collect baseline (BASE) data, all participants showed up in the laboratory on three occasions prior to the intervention (a description of the specific methods used is given in later sections). On the first visit, resting blood samples were collected to evaluate the concentration of bone turnover markers (BTM), and body weight, height, body composition including BMD and bone mass were measured. On the second visit, a dynamic balance test (four square step test) and a functional muscle strength and power test (jump-and-reach test) were performed. On the third visit, the aerobic capacity was evaluated by assessment of VO₂-max. After three weeks (3wk) of training, resting blood samples were additionally collected. After 19wk of training, all assessments were repeated and compared with baseline and MMT and CON were compared.

Blood sample collection, DXA-scanning, and VO₂-max tests were carried out at the Department of Nutrition, Exercise and Sports, University of Copenhagen, Denmark. The testing of vertical jump height, as well as dynamic balance, were performed at the health promotion training initiative in the Copenhagen area, Denmark. The blood samples were analyzed at the Department of Clinical Biochemistry, Rigshospitalet Glostrup Hospital, Denmark.

To ensure transparency of the study protocol, the trial was registered retrospectively at [ClinicalTrials.gov](https://clinicaltrials.gov) and published on December 21st, 2021 (NCT05164679). As registration at [ClinicalTrials.gov](https://clinicaltrials.gov) has until recently not been a part of the general research policy in our team, the trial was registered after completion of the study.

Participants

Healthy, sedentary postmenopausal women aged below 70 years were eligible to participate in the present study. Inclusion criteria were non-smoker and body mass index (BMI) <30 kg/m². Exclusion criteria were: T-score < -3 SD in

the lumbar spine or hip; Z-score > 1.5 SD (high age-related BMD); use of hormone therapy, medical treatment, or supplements that affect bone metabolism; previous or current medical condition affecting bone health; engagement in regular and systematic weight-bearing training or strength training during the preceding two years.

Initially, twenty women were recruited to the training via advertisements online and an in a local newspaper, of which 19 showed up for pre-testing (Figure 1). After a medical examination, one participant was excluded due to low BMD (T-score < -3 SD), and two were excluded due to high BMI ($\geq 30 \text{ kg/m}^2$). In addition, one woman refrained from participating in the training, and thus, 15 participants were recruited to MMT. During the study, two participants in MMT dropped out due to personal reasons and at the end of the study four participants were excluded in the analyses as their average attendance to the program was less than one hour per week. CON consisted of 13 age-matched sedentary postmenopausal women (12 from a previous study plus the woman who refrained from participating in the training), and therefore 9 MMT and 13 CON was finally included in the data analyses. Participants' baseline characteristics, including maximum oxygen consumption (VO₂-max), are shown in Table 1.

Every participant was fully informed in writing and verbally before giving her written consent to the procedures and potential discomfort associated with the study. The study was conducted in accordance with the Declaration of Helsinki and approved by the local ethics committee of the Capital Region of Denmark, H-18044190.

Figure 1. CONSORT flow diagram.

Training program

The present feasibility study evaluated the osteogenic impact of a training concept already offered by a health promotion initiative, “Knoglestærk” (“Bone strong”), in a local community.

According to the initiative, the training was offered as “evidence-based bone training” aimed upon enhancing musculoskeletal health. It was carried out 2×60 minutes weekly. The training concept included: 1) High- and odd-impact exercise including multi-directional games; 2) Progressive resistance training; 3) Balance and coordination training. The participants were engaged in intermittent gymnastics and small game sessions aimed at imposing osteogenic and diverse strain on the skeleton, mainly in the legs and arms. Thus, the training included various jumping exercises (e.g., counter-movement jumps, jumps from the floor up onto a bench, and from a bench down to the floor), quick walking up and down on gymnastics equipment, sprinting over short distances in different directions (in small games form). In addition, resistance exercises with elastic power bands, heavy exercise balls (medicine balls), and sandbags of 5-7 kg were applied. The training was performed intermittent and varied to ensure that the bones would not be desensitized, as it is observed in repetitive endurance training.

BMD and body composition

To test the BMD exclusion criteria at baseline as well as evaluate bone adaptation in proximal femur (PF), lumbar spine (LS), and whole-body (WB) after 19wk of training, BMD (g/cm^2) were assessed by Dual-energy X-ray Absorptiometry scanning (iDXA, Lunar Corporation, Madison, Wisconsin, USA) according to standard procedures. The regions of interests were determined by the enCore software (enCore software version 14.10.022, GE Medical Systems, Madison, United States). In addition, body composition was evaluated by the whole-body scan: body weight (BW, kg), BMI (kg/m^2), body fat percentage (%BF, %), total fat mass (FM, g), total lean body mass (LBM, g), visceral adipose tissue (VAT) mass (g) and volume (m^3), and total bone mineral content (BMC, g). The participants were asked to remove metal objects and empty their bladder prior to scanning.

Blood sampling & biochemical analyses

The plasma concentration of BTM at BASE, after 3wk, and after 19wk of training were measured. After an overnight fast and without any vigorous activities in the previous 48 hours, participants showed up in the laboratory in the early morning. Blood samples were collected from the antecubital vein with a butterfly needle, then transferred to EDTA tubes and centrifuged immediately. The plasma fractions were put on dry ice. Eighteen ml of blood were taken from each participant per test day. Following each test, a sample was placed at -80°C for future PINP, OC, and CTX analysis, which were assessed by the Chemiluminescence method using a fully automated immunoassay system (iSYS, Immunodiagnostic Systems Ltd., Bolton, England). The assay performance expressed as inter-run variation coefficients were 8% for PINP, 9% for OC, and 10% for CTX.

Training status

To estimate the participants' general training status, a progressive test of maximal oxygen uptake ($\text{VO}_{2\text{-max}}$) ($\text{ml}/\text{kg}/\text{min}$) was performed on an electronic bicycle ergometer (Monark 839E, Monark Exercise AB, Vansbro, Sweden) according to standard procedures. A breath-by-breath gas online analyzing system (Jaeger Oxycon Pro, VIASYS Healthcare, Höchberg, Germany) was connected to the participant, and a direct $\text{VO}_{2\text{-max}}$ measurement was conducted.

Dynamic balance

The “four square step test” (FSST) was performed to evaluate the dynamic balance¹⁸ in MMT. The test requires a person to move systematically forward, sideward, backward, and sideward again over four narrow sticks circa 2.5 cm in diameter and 100 cm in length placed on the floor like a cross. The participants were requested to complete the sequence as fast as possible without touching the sticks. Facing the cross, the participants started in the lower left quadrant by stepping forward over the stick into the next left quadrant, stepped sideward over the stick again into the upper right quadrant, and stepped backward over the stick into the lower right quadrant, then stepped sideward over the stick into the left quadrant where they started. Thus, they were moving in a clockwise direction. The floor in each square must be contacted by both feet, and the participants were asked to face forward for the whole sequence. However, the participants were allowed to turn to step into the next square if needed. They started and finished in the same square, and the score was given in seconds (sec). The test was done twice, and the fastest time was used as the FSST score.

Functional muscle strength and power

The functional muscle strength and power were evaluated in MMT by a jump-and-reach test (vertical jump height) (Vertec Sports Imports, Hilliard, OH). First, the participants were taught how to perform a countermovement jump and how to displace the vanes that was placed above reaching height on a vertical stand. After thoroughly instruction and familiarization, the jump-and-reach test was performed. The maximum vertical jump height (cm) was determined by the difference between the participant standing reach height and the highest displaced vane. The greatest value out of three trials was taken as the result.

Statistical analysis

All of the statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS, version 26.0, IBM Corp., Armonk, NY, USA). The standard descriptive statistics and unpaired T-test were used to describe and test the baseline characteristics of the participants. Repeated measurements ANOVA and general linear model with post hoc tests were used to test the effect of training on BTM, BMD, dynamic balance, and the jump-and-reach test. A p-value < 0.05 was considered significant. Unless otherwise stated, values are given as mean $\pm$ standard error (SE).

Results

Participant characteristics

At baseline, there were significant differences between MMT and CON for BW, BMI, FM, left and mean femur BMD values, OC, and CTX (Table 1).

Table 1. Baseline characteristics of the participants.

	MMT (n = 9)	CON (n = 13)	p-value
Age (years)	62.4 $\pm$ 3.8	58.7 $\pm$ 4.7	0.061
Height (cm)	166.9 $\pm$ 6.4	166.9 $\pm$ 5.2	0.989
Weight (kg)	72.8 $\pm$ 5.6	64.2 $\pm$ 10	0.022*
BMI (kg/m ²)	26.3 $\pm$ 2.2	22.9 $\pm$ 2.9	0.009*
Body Fat Percentage (%)	39.4 $\pm$ 3.1	33.7 $\pm$ 8.5	0.070
Total Fat Mass (kg)	28.7 $\pm$ 2.7	22.2 $\pm$ 8.6	0.043*
Total Lean Body Mass (kg)	41.8 $\pm$ 4.3	39.8 $\pm$ 3.4	0.233
VAT-mass (g)	793 $\pm$ 351.2	511 $\pm$ 434.8	0.123
VAT-volume (cm ³)	840.6 $\pm$ 372.2	541.7 $\pm$ 460.9	0.123
Total BMC (g)	2266.9 $\pm$ 206.5	2067.2 $\pm$ 300.2	0.100
BMD (g/cm ²)			
Whole-body	1.121 $\pm$ 0.073	1.046 $\pm$ 0.099	0.066
Lumbar spine	1.088 $\pm$ 0.137	1.014 $\pm$ 0.111	0.175
Right Femur neck	0.918 $\pm$ 0.092	0.834 $\pm$ 0.097	0.057
Left Femur neck	0.941 $\pm$ 0.088	0.823 $\pm$ 0.076	0.003*
Mean Femur neck	0.929 $\pm$ 0.089	0.829 $\pm$ 0.085	0.015*
Right Total Femur	0.947 $\pm$ 0.098	0.864 $\pm$ 0.091	0.056
Left Total Femur	0.949 $\pm$ 0.101	0.840 $\pm$ 0.091	0.016*
Mean Total Femur	0.948 $\pm$ 0.098	0.852 $\pm$ 0.090	0.028*
Right Trochanter	0.741 $\pm$ 0.087	0.683 $\pm$ 0.092	0.149
Left Trochanter	0.745 $\pm$ 0.091	0.661 $\pm$ 0.097	0.055
Mean Trochanter	0.743 $\pm$ 0.086	0.672 $\pm$ 0.093	0.084
Right Shaft	1.151 $\pm$ 0.126	1.046 $\pm$ 0.125	0.068
Left Shaft	1.149 $\pm$ 0.131	1.008 $\pm$ 0.121	0.017*
Mean Shaft	1.150 $\pm$ 0.126	1.027 $\pm$ 0.121	0.033*
BTM			
P1NP (μ g/l)	52.8 $\pm$ 16.6	62.1 $\pm$ 21.3	0.298
OC (μ g/l)	19 $\pm$ 6.5	28.9 $\pm$ 7.1	0.003*
CTX (ng/l)	331.2 $\pm$ 100.7	627.8 $\pm$ 253.8	0.001*
VO ₂ -max (ml/min/kg)	28.2 $\pm$ 3.6	30.5 $\pm$ 4.7	0.204

Values are given as means $\pm$ SD. BMI = body mass index, BMD = bone mineral density, BTM = bone turnover marker.

*Significant difference between groups (p < 0.05). Unpaired T-test.

Attendance and dropout

As described in the participants section, two persons in MMT dropped out due to personal reasons, and four participants did not meet the mean attendance criterion of at least 1 session weekly (>19 sessions) and were subsequently excluded in the data analyses. The mean attendance rate for the remaining participants (9 women) was 24.2 sessions (65.5%) of the maximum number of sessions offered (37 sessions). The individual attendance rates were 20-30 sessions (54.1-81.1%), with a decrease in attendance rate over time from 6.2 out of 8 sessions (78%) in the first four-week period and 5.1 out of 8 sessions (64%) in the last four-week period.

The attendance rate range (54.1-81.1%) in the present study showed that there is inter-individual variability. The participants attended the training more in the first than the last four-week.

BMD and body composition

After 19wk of training, right trochanter BMD (g/cm^2) increased significantly from baseline for MMT (1.0%, $p = 0.03$), which was significantly different from CON ($p = 0.03$) (Table 2), but there was no significant BMD change in any other region. However, LS (1.2%) and right total femur (0.3%) tended to increase (both, $p < 0.1$) for MMT (Figure 2). Whole-body BMC decreased significantly (0.7%, $p = 0.016$) within CON.

For body composition, there were significant reductions in %BF (4.0%, $p = 0.006$), FM (6.0%, $p = 0.013$), VAT-mass (11.3%, $p = 0.004$), VAT-volume (11.3%, $p = 0.004$) within the MMT compared to BASE (Table 3). Compared to CON, there were significant differences for %BF ($p = 0.049$), FM ($p = 0.021$), VAT-mass ($p = 0.013$), VAT-volume ($p = 0.013$), and whole-body BMC ($p = 0.041$) delta values.

BTM

The plasma concentrations of PINP, OC, and CTX are shown in Figure 3 and Table 4. There was no significant within- or between-group difference observed at 3wk or 19wk compared to baseline for all markers.

FSST & Jump-and-reach test

There were no significant changes in both FSST and jump-and-reach test at 19-week compared to baseline for MMT (Table 5). However, there was a tendency to be faster in FSST at 19-week ($p = 0.06$).

Table 2. Absolute BMD values (Mean $\pm$ SD).

	MMT (n = 9)		CON (n = 13)		p-value ^a
	Baseline	19wk	Baseline	19wk	
Whole body	1.121 $\pm$ 0.073	1.119 $\pm$ 0.070	1.046 $\pm$ 0.099	1.045 $\pm$ 0.099	0.873
Lumbar spine	1.088 $\pm$ 0.137	1.100 $\pm$ 0.128	1.014 $\pm$ 0.111	1.005 $\pm$ 0.110	0.067
Right Femur neck	0.918 $\pm$ 0.092	0.920 $\pm$ 0.104	0.834 $\pm$ 0.097	0.829 $\pm$ 0.088	0.359
Left Femur neck	0.941 $\pm$ 0.088	0.939 $\pm$ 0.083	0.823 $\pm$ 0.076	0.817 $\pm$ 0.079 [#]	0.337
Mean Femur neck	0.929 $\pm$ 0.089	0.929 $\pm$ 0.092	0.829 $\pm$ 0.085	0.823 $\pm$ 0.081	0.149
Right Total Femur	0.947 $\pm$ 0.098	0.950 $\pm$ 0.104	0.864 $\pm$ 0.091	0.857 $\pm$ 0.086	0.054
Left Total Femur	0.949 $\pm$ 0.101	0.947 $\pm$ 0.088	0.840 $\pm$ 0.091	0.837 $\pm$ 0.092	0.763
Mean Total Femur	0.948 $\pm$ 0.098	0.948 $\pm$ 0.094	0.852 $\pm$ 0.090	0.847 $\pm$ 0.088	0.136
Right Trochanter	0.741 $\pm$ 0.087	0.749 $\pm$ 0.090 [#]	0.683 $\pm$ 0.092	0.677 $\pm$ 0.093	0.026 [*]
Left Trochanter	0.745 $\pm$ 0.091	0.746 $\pm$ 0.073	0.661 $\pm$ 0.097	0.660 $\pm$ 0.099	0.771
Mean Trochanter	0.743 $\pm$ 0.086	0.747 $\pm$ 0.077	0.672 $\pm$ 0.093	0.669 $\pm$ 0.095	0.129
Right Shaft	1.151 $\pm$ 0.126	1.154 $\pm$ 0.140	1.046 $\pm$ 0.125	1.040 $\pm$ 0.118	0.333
Left Shaft	1.149 $\pm$ 0.131	1.142 $\pm$ 0.117	1.008 $\pm$ 0.121	1.006 $\pm$ 0.121	0.502
Mean Shaft	1.150 $\pm$ 0.126	1.148 $\pm$ 0.126	1.027 $\pm$ 0.121	1.023 $\pm$ 0.118	0.681

Notes: BMD values indicate g/cm^2 . MMT = Multimodal training group, CON = Control group.

^aGeneral Linear Model + post hoc test.

^{*}Significant difference between group ($p < 0.05$).

[#]Significant difference within group ($p < 0.05$).

Figure 2. Percent change ($\pm$ SE) in whole-body and regional bone mineral density (BMD) following the 19-week multimodal training. *Significant between-group difference ($p < 0.05$). #Significant within-group difference ($p < 0.05$).

Table 3. Body composition values (Mean $\pm$ SD).

	MMT (9)		CON (n = 13)		p-value ^b
	Baseline	19wk	Baseline	19wk	
Weight ^a (kg)	72.8 $\pm$ 5.6	71.2 $\pm$ 5.3	64.2 $\pm$ 10.3	63.8 $\pm$ 10.3	0.162
BMI (kg/m ²)	26.3 $\pm$ 2.2	25.9 $\pm$ 2.4	22.9 $\pm$ 2.9	22.9 $\pm$ 3	0.258
%BF (%)	39.4 $\pm$ 3.1	37.8 $\pm$ 2.7 [#]	33.7 $\pm$ 8.5	33.5 $\pm$ 8	0.049 [*]
Total Fat Mass (kg)	28.7 $\pm$ 2.7	26.9 $\pm$ 2.7 [#]	22.2 $\pm$ 8.6	22 $\pm$ 8.3	0.021 [*]
Total Lean Mass (kg)	41.8 $\pm$ 4.3	42 $\pm$ 3.8	39.8 $\pm$ 3.4	39.7 $\pm$ 3.4	0.673
VAT-mass (g)	793 $\pm$ 351.2	694 $\pm$ 307 [#]	511 $\pm$ 434.8	508.8 $\pm$ 421.5	0.013 [*]
VAT-volume (cm ³)	840.6 $\pm$ 372.2	735.7 $\pm$ 325.4 [#]	541.7 $\pm$ 460.9	539.4 $\pm$ 446.8	0.013 [*]
Whole-body BMC (g)	2266.9 $\pm$ 206.5	2269.8 $\pm$ 202.4	2067.2 $\pm$ 300.2	2052.6 $\pm$ 301.3 [#]	0.041 [*]

MMT = Multimodal training group, CON = Control group, BMI = Body Mass Index.

^aGeometric mean.

^bGeneral Linear Model + post hoc test.

^{*}Significant difference between groups ($p < 0.05$).

[#]Significant difference within-group ($p < 0.05$).

Figure 3. Bone turnover markers. (A) Procollagen type-1 amino-terminal propeptide (P1NP), (B) osteocalcin (OC), and (C) C-terminal telopeptide of type-1 collagen (CTX). Time measurements: Immediately before exercise (baseline), after 3 weeks (3wk), after 19 weeks (19wk). The lines represent means $\pm$ SE.

Table 4. Bone turnover marker (BTM) concentrations at BASELINE, after 3 weeks of training (3wk), and after 19 weeks of training (19wk).

Outcome	Group	BASELINE	3wk	19wk	p-value within-group	p-value between-group
Markers of bone formation						
P1NP (µg/L)	MMT (n = 9)	52.8 ± 5.5	58.8 ± 4.5	58.4 ± 4.8	0.193	0.304
	CON (n = 13)	62.1 ± 5.9	69.7 ± 7.3	62.4 ± 5.9	0.218	
OC (µg/L)	MMT (n = 9)	19.0 ± 2.2	19.6 ± 1.7	20.0 ± 1.4	0.810	0.231
	CON (n = 13)	28.9 ± 2.0	25.1 ± 1.8	24.8 ± 2.6	0.173	
Marker of bone resorption						
CTX (ng/L)	MMT (n = 9)	331.2 ± 33.6	356.6 ± 32.2	374.8 ± 18.5	0.330	0.394
	CON (n = 13)	627.8 ± 70.4	678.2 ± 82.1	729.5 ± 115.8	0.243	

Notes: All values are expressed as mean ± SE. P1NP = procollagen type-1 amino-terminal propeptide, OC = Osteocalcin, CTX = C-terminal telopeptide of type 1 collagen, MMT: Multimodal training, CON: Control. Repeated measurement ANOVA.

Table 5. Dynamic balance and functional muscle strength result for multimodal training group (n=9). Paired t-test.

	Mean ± SD	Difference ± SD	CI-95%	p-value
Four Squared Step Test (sec)				
Baseline	7.5 ± 1.0	0.6 ± 0.8	−0.04 – 1.2	0.062
19wk	6.9 ± 0.8			
Jump and reach test (cm)				
Baseline	20.2 ± 6.1	−1.3 ± 3.7	−4.2 – 1.5	0.308
19wk	21.6 ± 6.3			

Discussion

The present study aimed at evaluating the feasibility and whether 19wk of multimodal training offered as musculoskeletal health promotion in a local community had an effect on musculoskeletal health, body composition, dynamic balance, and functional muscle strength in postmenopausal women. The main finding from this study was that the training program had a positive effect on body composition. Thus, %BF, FM, VAT-mass, and VAT-volume were significantly reduced in MMT compared to CON, showing that the body composition change was due to the training program. In addition, the right trochanter BMD was improved for MMT, and the whole-body BMC was maintained for MMT in contrast to a significant reduction in CON.

This study found that only right trochanter BMD was significantly increased (1.0%, $p < 0.05$) in MMT. There was no significant changes in other regions of BMD. This finding could be due to the participant attendance did not meet the recommendations of training intensity, volume, and frequency. According to Daly and Giangregorio,¹⁹ the minimum frequency of resistance training is at least two days per week and for weight-bearing impact exercise 4-7 times per week, which the present study not met as no participant fulfilled 37 times in total for 19wk of training.

The whole-body BMC was not changed in MMT, whereas it was significantly decreased ($p = 0.02$) by 0.7% in CON, which was significantly ($p = 0.04$) different from MMT (Table 3). Thus, it seems from the present study that the training at “Knoglestærk” maintained total bone mass, even with a required minimum training attendance of just one hour weekly. The loss of whole-body BMC (−0.7%, $p = 0.016$) in CON group is consistent with Gallagher *et al.*,²⁰ who investigated the effect of age and menopause status on bone. The finding that the change in BMC differed between MMT and CON is not in line with Mosti *et al.*,¹⁶ who investigated the impact of three sessions of squat exercise maximal strength training in postmenopausal women with osteoporosis or osteopenia (mean age: 61.9 ± 5.0 y) for 12 weeks. Moreover, they found an increase in lumbar spine BMC not whole-body. Thus, they found an increase of $2.9 \pm 2.8\%$ ($p = 0.01$) LS BMC from baseline in training group, and this change was higher ($p = 0.03$) than in control group.

The reduction in %BF and FM (Table 3) in this study is in agreement with Daly *et al.*,²¹ who investigated the effect of one year supervised and structured multi-component training program in community-dwelling independently living men (27%) and women (73%) (mean age: 67.4 y, 60-86 years). They found that the FM was significantly decreased ($p < 0.001$) by 3.2%, which is lower than the present study (6.0%, $p = 0.01$). The higher reduction in the present study compared to Daly *et al.*²¹ study might be due to the younger participant (62.4 ± 3.8 y) which has a higher metabolic rate than the older one (66–94 y),²² that could influence the change of body fat. The reduction in %BF and FM is in line with Nielsen *et al.*²³ as well, who investigated the feasibility and physiological health effects of 15-week training performed minimum once a week for sedentary elderly. They found that the total FM was significantly decreased (-2.0 kg, $p = 0.01$) and the %BF as well (-1.6% , $p = 0.01$).

As the VAT assessment by iDXA is a fairly new functionality, only very few studies report results for this outcome, and it seems that none has studied training effects on VAT for healthy postmenopausal women. Moreover, no normal reference intervals for specific populations are established yet. The present finding of a 11.3% reduction in VAT seems in line with the Yen *et al.* study,²⁴ which reported a 6.3% decrease in VAT after eight weeks of aerobic and resistance exercise intervention. However, the study participants were a group of male and female patients receiving chemotherapy for head and neck cancer (mean age: 52 ± 10.7 y). As reported by Yen *et al.*²⁴ the lower response than the present study (-6.3% vs. -11.3%) may be due to the disease or the shorter duration (8wk vs. 19wk), even though their intervention more frequent (3 days/week vs. one day/week).²⁵ Moreover, it could be hypothesized that the participants in Yen *et al.*²⁴ study had a lower %BF and VAT at baseline, therefore, it is more difficult to induce a training response. Nevertheless, more studies still needed on healthy postmenopausal women.

Despite the favorable result, the present study has several limitations. The dietary intakes were not recorded. Thus, the changes that occur in the body composition could not be known whether entirely due to the training or dietary intake of participants. Future studies should consider taking the dietary intake history and monitoring habitual daily physical activity, which may add an explanation regarding the changes specifically in body composition in the present study. Another thing to note is that the *Knoglestærk* health promotion program is a real-life setting and thus the training is not as well controlled as in a laboratory setting. Because neither heart rate (HR) nor accelerometer measurements were recorded during exercise, it cannot be ruled out that the individual training intensity varied among the participants. Hence, the use of HR monitor and accelerometer would improve the control and the standardization of the training and thus reduce the variation in the individual response and the reliability of the results. In addition, we did not carry out a priori power analyses. The power calculations were performed after the studies had been conducted (provided as *Extended data*²⁶), and the statistical power of the present study seems to be underpowered. Therefore, a larger sample size would have a positive effect on the effect sizes due to a reduction in standard error and thus an improvement of the statistical power. The effect size of the intervention was varied, with greatest effect on VAT-volume & masse, total BMC, weight, total fat mass and body fat percentage. On the contrary, the intervention has smaller effect on general and specified BMDs. The given amount of time (19wk) and specified intervention (multimodal training group) had greater effect on fat changes rather than bone changes. The interesting part was the total BMC that affected by the intervention was not followed by BMD's changing.

Conclusions

The results of the present study indicate that while 19 weeks of multimodal musculoskeletal training as offered by the *Knoglestærk* health promotion training initiative is feasible for postmenopausal women by inducing health-enhancing effects on body composition, however due to the attendance compliance, the training did only elicit minor significant improvements in BMD, thus an increase was found in right trochanter BMD and whole-body BMC. No changes in dynamic balance or the functional muscle strength were observed in the present study. To promote musculoskeletal improvements for all participants, a better control of the individual musculoskeletal training intensity, frequency, and attendance rate is highly recommended.

Data availability

Underlying data

Figshare: Underlying data for 'A Feasibility Study of Training in a Local Community Aimed Upon Health Promotion with Special Emphasis on Musculoskeletal Health Effects.'

<https://doi.org/10.6084/m9.figshare.16836940>.²⁹

This project contains the following underlying data:

- A Feasibility Study of Training Dataset1.csv (dataset of participant characteristic, body composition, and bone mineral density)

- A Feasibility Study of Training Dataset2.csv (dataset of participants' bone turnover markers)
- A Feasibility Study of Training Dataset3.csv (dataset of functional muscle strength and power and dynamic balance result)

Extended data

Figshare: Working title: A Feasibility Study of Training in a Local Community Aimed Upon Health Promotion with Special Emphasis on Musculoskeletal Health Effects. Extended data - Statistical power of the paired t-tests for body composition, regional BMD, and bone turnover markers. <https://doi.org/10.6084/m9.figshare.16611655.v1>²⁶

Figshare: Working title: A Feasibility Study of Training in a Local Community Aimed Upon Health Promotion with Special Emphasis on Musculoskeletal Health Effects. Extended data - Effect size of the Training Program. <https://doi.org/10.6084/m9.figshare.16611787.v1>²⁷

Reporting guidelines

Figshare: CONSORT checklist, extension for Pilot and Feasibility Trials for study "A Feasibility Study of Training in a Local Community Aimed Upon Health Promotion with Special Emphasis on Musculoskeletal Health Effects". <https://doi.org/10.6084/m9.figshare.16610341.v1>²⁸

Data are available under the terms of the [Creative Commons Zero "No rights reserved" data waiver](#) (CC0 1.0 Public domain dedication).

Acknowledgements

We thank all the participants who took part in the study for their time and efforts. The authors thank Jens J. Nielsen for assistance in blood draws, Nadia Quardon for blood sample analysis, Andreas Meine for assistance in VO₂-max testing, and Christian Ritz for support in statistics. RSP gratefully acknowledges a Ph.D. fellowship from Lembaga Pengelola Dana Pendidikan (LPDP)/Indonesia Endowment Fund for Education.

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[Publisher Full Text](#)

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Robert Wen-Wei Hsu

Department of Orthopaedic Surgery, Chang Gung Memorial Hospital, Pu-Tz City, Taiwan

Thank you for sending this paper for reviewing. There were some comments on the following:

1. The sample size is too small to validate the effect of training.
2. How was the sample size determined?
3. Statistical power should be calculated.
4. The exercise program is not strong enough to have physiological impact to the health.
5. The duration of exercises is not long enough.
6. The study is required to do prospective study. The assignment to exercise and control group should be randomized.

Is the work clearly and accurately presented and does it cite the current literature?

No

Is the study design appropriate and is the work technically sound?

No

Are sufficient details of methods and analysis provided to allow replication by others?

No

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

No

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Orthopedics, sports medicine

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 28 Feb 2023

Rizky Suganda Prawiradilaga

1. We are aware of that. We tried to equate the number of samples with our previous studies but, in our feasibility study with community settings, it turned out that 6 people from the MMT group dropped out.
2. The sample size was determined by the Author judgement based on the previous study on Bone Turnover Markers ([Prawiradilaga et al. \(2020\)](#)).
3. The Statistical power calculations were performed with Power and Sample Size Calculations version 3.0 for the paired t-test and performed with SPSS for the repeated ANOVA measurement. The results are in the [link](#) in the 'Extended data' section.
4. We apologize; we do not actually understand, what do you mean by not strong enough? The Health initiative program uses multimodal training including 1) High- and odd-impact exercise including multi-directional games; 2) Progressive resistance training (PRT); 3) Balance and coordination training which has an osteogenic impact based on evidence, but we are aware that frequency, duration did not meet the recommendation. In addition, we didn't measure the heart rate for intensity.
5. We understand that the Health Promotion initiative program was not long enough (19 weeks) and did not meet the recommendation (6-12 months) for osteogenic exercise. We would like to see whether there were bone turnover markers (BTM) changes in this short period since, in our previous study, there were acute responses in BTM.

Thank you for your suggestions.

- Is the work clearly and accurately presented and does it cite the current literature?

We have cited the current literature

- Is the study design appropriate and is the work technically sound?

We have added, "This is a feasibility study in a local community with a non-randomized controlled trial approach."

- Are sufficient details of methods and analysis provided to allow replication by others?

We think it is sufficient since the study method and the training program were described

clearly.

- Are all the source data underlying the results available to ensure full reproducibility?

We share the raw data in the 'Extended data' section.

Competing Interests: The authors have no professional relationships with companies or manufacturers that might benefit from this study. The results do not constitute an endorsement of any product.

Reviewer Report 16 May 2022

<https://doi.org/10.5256/f1000research.77367.r134828>

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Melanie Kistler-Fischbacher

Menzies Health Institute Queensland, Griffith University, Gold Coast, Qld, Australia

This non-randomised controlled study reports the effect of a 19-week multicomponent exercise intervention (resistance, balance and impact training) on bone markers, bone mineral density and body composition outcomes among 28 postmenopausal women. I have concerns about the study design and methodological rigor of the trial. Specifically, the duration of the trial 19 weeks is insufficient to detect changes in bone, bias associated with the differences between groups at baseline and the lack of adjustment for multiple comparisons.

Introduction

Paragraph (P) 1: "is it estimated that 200 million females...". This number actually includes males and females.

P2: "One way to prevent... age-related bone loss". This is a very old reference. Since 1987 a large number of exercise trials for bone have been conducted. I suggest including a more recent reference.

P3 & 4: In para 3 you hypothesize that "evidence-based multimodal training will have an osteogenic effect and in para 4 you state that there is a need for "evidence-based trainings". This is contradicting and I don't think you can call this MMT "evidence based"

P4: "Only few studies have examined...". There has been a large number of studies that have tested combined impact, resistance and balance training interventions in recent years which showed safety and efficacy. ^{1,2,3,4} These should be cited here plus the existing gap in the literature identified.

P5: "The aim was to investigate the feasibility..." Feasibility is mentioned in the title, the aims and discussion (e.g. discussion 1st sentence and conclusion 1st sentence), however, it is unclear how feasibility was measured. Feasibility is also not listed as an endpoint (e.g. clinicaltrials.gov). Please clarify.

Methods

General: please clarify which outcomes were primary and which ones were secondary.

P1: Please explain how participants were recruited, particularly the sedentary control group.

P1: The duration of 19 weeks is inappropriate to measure changes in bone mineral density. A minimum of 6-8 months is needed to detect changes in bone.

P3: "to ensure transparency" The trial was registered close to manuscript submission data, which does not ensure transparency. I suggest deleting this part of the sentence.

P4: How was sedentary defined?

- Was there a minimum age set?
- How was postmenopausal defined? (e.g. how many years post menopause?)
- How was regular, systematic training defined?

P5: The information on the number of participants and drop outs should be moved to the results section.

P5: "...12 from a previous study...". Please describe the control group somewhere.

P8: How many sets and repetitions were performed of each exercise, and how did you ensure the resistance training was progressive?

P9: Can you include information on the short-term measurement variability of BMD and body composition measures in your lab?

P12/13: Why were FSST and jump-and-reach tests not performed in the control group?

P14: Given the large number of outcomes, adjustment for multiple comparison is strongly recommended.

Results

P1: There are significant baseline differences between groups which is of great concern. How did you address this, were analyses adjusted for baseline values?

P4: "... LS and total femur... tended to increase". Reporting of trends is controversial; I suggest removing this sentence.

Table 2: Please explain why you are reporting mean femur BMD in addition to right and left femur values.

Table 2/3: Your findings show a decrease in whole body BMC and an increase in BMD. How would you explain these differences.

Discussion

Rather than comparing present findings to individual studies, I would recommend reviewing the large body of systematic reviews and meta-analyses on the topic. Many of those have examined the influence of training parameters (e.g. intensity, volume and frequency. ^{3,5}) Interpretation of your findings in context of those findings would be helpful. For example, recent studies have shown that exercise intensity is positively associated with bone changes, and that low-intensity exercise is ineffective.

There are a number of limitations of the present study that have not been addressed in the discussion. E.g. bias related to baseline differences, not randomised, only short term (< 6 months), generalisability.

You state that no power calculation was undertaken. 1) How was the sample size determined? 2) How was a posteriori power calculated and what were the results?

I would like to see a section about clinical significance of the findings.

Conclusion

“... inducing health-enhancing effects”. In light of the significant baseline differences, other study limitations and the fact that only body composition variables (which were significantly different between groups at BL) improved, I think this is overstating the findings of the study.

References

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Is the work clearly and accurately presented and does it cite the current literature?

No

Is the study design appropriate and is the work technically sound?

No

Are sufficient details of methods and analysis provided to allow replication by others?

No

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Exercise science; bone; bone-specific exercise; osteoporosis; weight lifting for bone and muscle health; postmenopausal women

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 28 Feb 2023

Rizky Suganda Prawiradilaga

Introduction

P1: We are sorry if we were mistaken. We got it from the Facts and Statistics International Osteoporosis Foundation (IOF) [cited 2017 Oct 4]. Some other references that said the same that 200 million women: [COLOSTEO](#) (the project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 778277)¹, and de Villiers and Goldstein (2022)².

P2: Thank you. We have changed the reference to: Zhang S, Huang X, Zhao X, Li B, Cai Y, Liang X, *et al.* Effect of exercise on bone mineral density among patients with osteoporosis and osteopenia: A systematic review and network meta-analysis. *J Clin Nurs*. 2022 Aug; **31** (15–16):2100–11.

P3 & 4: We agree with you, we have changed a little bit “it is hypothesized in the present study that evidence-based multimodal training as health promotion will have an osteogenic effect” into “it is hypothesized in the present study that training (which combined evidence-based exercise) as health promotion will have an osteogenic effect”. We have revised it.

P4: We have added the references:

- Watson SL, Weeks BK, Weis LJ, *et al.*: High-Intensity Resistance and Impact Training Improves Bone Mineral Density and Physical Function in Postmenopausal Women With Osteopenia and Osteoporosis: The LIFTMOR Randomized Controlled Trial. *J Bone Miner Res*. 2018 Feb; **33**(2):211–220. [PubMed Abstract](#) | [Publisher Full Text](#)
- Kistler-Fischbacher M, Yong JS, Weeks BK, *et al.*: A Comparison of Bone-Targeted Exercise With and Without Antiresorptive Bone Medication to Reduce Indices of Fracture Risk in Postmenopausal Women With Low Bone Mass: The MEDEX-OP Randomized Controlled Trial. *J Bone Miner Res*. 2021; **36**(9):1680–1693. [Publisher Full Text](#)
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P5: Thank you for the suggestion, We have added attendance rate as a feasibility endpoint in the Methods section. The feasibility outcome is already in the Results section.

Methods

General: We have clarified which outcomes were primary and which ones were secondary.

P1: It was explained in Participants section in then Methods section. The sedentary control group was from a previous study (which hasn't been published) not a long time before the present study. The recruitment process itself was the same, via advertisement online and a local newspaper.

P1: Yes, we understand. The bone turnover occurs around 5 to 6 months, and we can detect the changes around that time of intervention. However, our study regarding the bone turnover marker (Prawiradilaga *et al.* (2020)³) showed that acute exercise has an acute response on bone marker (P1NP). Regarding that, we hope that we can see the change in bone turnover markers as well as the bone mineral density in only 19 months. Why only 19 months? It was the feasible range of time we can manage before everyone went to summer vacation.

P3: Alright, thank you. We have deleted that part.

P4: Sedentary is defined as someone who didn't engage in regular and systemic weight-bearing training or strength training in the last 2 years. We have added a note to distinguish active from sedentary.

- No minimum age, only maximum 70.
- 2 years post menopause
- Minimum at least 1 time a week, has a goal of the training.

P5: We have considered your suggestion and have moved the number of participants and drop outs to the Results section.

P5: Thank you.

P8: The progressive resistance training (PRT) consisted primarily of exercises using own bodyweight, with occasional use of medicine balls, resistance bands and sandbags (5–15 kg), starting with 15–20RM and slowly progressing to 6–12RM, with 2–3 sets. We have added this in the manuscript.

P9: We don't think we have the information on short-term of BMD and body composition. We only measure the bone turnover markers for the short-term.

P12/13: They did not want to do the test.

P14: Thank you for the suggestion.

Results

P1: Our analyses were based on the delta values.

P4: Thank you for your suggestion. We have removed "However, LS (1.2%) and right total femur (0.3%) tended to increase (both, $p < 0.1$) for MMT".

Table 2: We think it is good information to give the reader the mean femur BMD.

Table 2/3: There is significant difference between MMT and Control (CON) group. While the whole-body BMC showed decrease in CON group, the whole BMC in MMT group doesn't change. It showed that the training might inhibit the whole-body BMC to decrease in postmenopausal women. The whole-body BMD was not increased, however, the right trochanter BMD in MMT was increased compared to CON.

Discussion

Thank you for the suggestion, We have added regarding the recent studies which have shown that exercise intensity is positively associated with bone changes, and that low-intensity exercise is ineffective.

Thank you for your suggestions, we have addressed other limitations.

1. The sample size was determined by the Author judgement based on the previous study on Bone Turnover Markers (Prawiradilaga *et al.* (2020)³.
2. The posteriori power calculations were performed with Power and Sample Size Calculations version 3.0 for the paired t-test and performed with SPSS for the repeated ANOVA measurement. The results are in the [link](#) in the 'Extended data' section.

- Is the work clearly and accurately presented and does it cite the current literature?

We have cited the current literature

- Is the study design appropriate and is the work technically sound?

We have added, "This is a feasibility study in a local community with a non-randomized controlled trial approach."

- Are sufficient details of methods and analysis provided to allow replication by others?

We think it is sufficient since the study method and the training program were described clearly.

References

1. Osteoporosis Facts [Internet]. COLOSTEO. [cited 2022 Aug 12]. Available [online](#) (date last accessed: 10/03/2023)
2. de Villiers TJ, Goldstein SR: Bone health 2022: an update. *Climacteric*. 2022 Jan 2; **25**(1):1–3. [Publisher Full Article](#)
3. Prawiradilaga R, Madsen A, Jørgensen N, *et al.*: Acute response of biochemical bone turnover markers and the associated ground reaction forces to high-impact exercise in postmenopausal women. *Biol Sport*. 2020; **37**(1): 41–48. [PubMed Abstract](#)

Competing Interests: The authors have no professional relationships with companies or manufacturers that might benefit from this study. The results do not constitute an endorsement of any product.

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