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Effects of a 12-Month Resistance Training Program on Physical Performance, Muscle Strength, Pain, and Health-Related Quality of Life in Postmenopausal Women with Osteoporosis

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Abstract: Postmenopausal osteoporosis is associated with reduced muscle strength, functional limitations, and impaired quality of life, particularly due to increased pain. This study aimed to evaluate the effects of a 12-month strength training program on physical performance and quality of life in women with postmenopausal osteoporosis and to determine whether physical performance and muscle strength influence pain levels. Thirty-nine women were allocated to an exercise group (n = 20) or a control group (n = 19). After 12 months, the exercise group demonstrated significantly greater improvements than the control group in Arm Curl ($p<.001$, $\eta^2_p=.33$), Chair Stand ($p<.001$, $\eta^2_p=.33$), dominant handgrip strength ($p=.001$, $\eta^2_p=.24$), and non-dominant handgrip strength ($p=.003$, $\eta^2_p=.21$). Pain reduction was significantly greater in the exercise group ($p<.001$, $\eta^2_p=.59$), along with improvements in activities of daily living ($p<.001$, $\eta^2_p=.31$), perceived health ($p<.001$, $\eta^2_p=.48$), and mental state ($p<.001$, $\eta^2_p=.31$). Regression analyses showed that post-intervention Chair Stand performance explained 41% of pain variance ($R^2=.410$, $p<.001$), while Arm Curl explained 57% ($R^2=.573$, $p<.001$). Significant negative correlations were observed between pain and Arm Curl ($p<.001$), Chair Stand ($p<.001$), dominant ($p=.001$) and non-dominant handgrip strength ($p=.003$), with correlation coefficients ranging from $r=-.46$ to $-.70$ ($p<.01$). The decrease in pain has important clinical implications, as reduced pain levels may facilitate mobility, enhance daily functioning, and support long-term independence in women with osteoporosis. These findings indicate that long-term strength training produces clinically meaningful improvements in physical performance and quality of life and that pain reduction is strongly associated with gains in muscular and functional capacity.

Keywords: osteoporosis, quality of life, physical performance

1. Introduction

Postmenopausal osteoporosis, driven by the sharp decline in estrogen, accelerates bone turnover, favoring resorption over formation. Progressive disease leads to back pain, fractures, spinal deformities, and systemic complications, imposing physical, psychological, and economic burdens. Fractures, particularly hip fractures, represent the most severe consequence, with high morbidity, mortality, prolonged recovery, and substantial healthcare costs, profoundly impacting quality of life in postmenopausal women. Estrogen tightly regulates bone metabolism, making menopause a critical period for osteoporosis risk. Fragility fractures are the primary outcomes to prevent. Since aging compounds postmenopausal risk, early preventive strategies—such as physical activity, adequate nutrition, and avoidance of smoking and excess alcohol—are essential. Assessment of risk factors, including prior fractures, family history, or age over 65, should guide further evaluation with bone densitometry [1]. The beneficial role of physical activity in preserving and promoting health among older adults has been extensively established in the literature [2]. Engagement in regular physical activity in later life is associated with a reduced incidence of chronic disease, improved management of existing health conditions, and the maintenance and enhancement of both physical and cognitive functioning [3]. Conversely, physical inactivity—defined as failure to meet established physical activity guidelines—is linked to a heightened risk of developing metabolic and cardiovascular disorders, including diabetes mellitus and cardiovascular disease [4], [5], [6]. In addition, insufficient physical activity contributes to progressive declines in muscle mass and neuromuscular performance, such as reductions in muscle strength and power, which in turn exacerbate impairments in mobility and functional independence. Recent evidence highlights that exercise programs combining multiple components, particularly those including demanding balance tasks, are effective in reducing fall risk. Clinical trials suggest that supervised, progressively intensified resistance and impact training (HiRIT) can safely improve lumbar spine bone density in postmenopausal women with osteoporosis or osteopenia. However, the long-term sustainability of these bone gains and the safety of such high-load interventions in individuals with recent fractures remain unclear. Overall, exercise has the potential to confer multifaceted skeletal benefits by simultaneously promoting bone formation through high-intensity loading and preventing falls via balance training. [7]. Exercise-based interventions represent a key non-pharmacological approach for both the prevention and management of osteoporosis after menopause, although the most effective training modalities remain a topic of debate. Training protocols characterized by moderate to high intensity, rapid execution, and short bouts appear to elicit favorable adaptations in bone turnover, regardless of the exercise environment [8]. The QUALEFFO 41 questionnaire is widely used in studies of women with osteoporosis [9]. In older adults with osteoporosis, fear of falling (FOF) is a major determinant of reduced health-related quality of life. This persistent anxiety often limits physical activity, lowers self-efficacy, and promotes physical deconditioning. FOF affects nearly 44% of this population, creating a cycle where inactivity worsens physical decline, elevates fall risk, and reinforces fear. Notably, the psychological impact of FOF can impair quality of life more than falls themselves, by increasing functional limitations, reducing social participation, and heightening anxiety and depression [10], [11], [12].

Although physical exercise is recognized as an effective non-pharmacological strategy for osteoporosis management, evidence concerning long-term structured resistance training in postmenopausal women remains limited. In particular, there is insufficient information regarding the combined effects of strength-oriented programs on functional performance and quality of life. The present study was designed to address this gap by examining the long-term outcomes of a supervised resistance training intervention in women with postmenopausal osteoporosis.

This research aimed to examine the prolonged impact of a systematic resistance training regimen on both functional capacity and overall well-being in postmenopausal women diagnosed with osteoporosis. In addition to evaluating changes in muscular strength and functional capacity, the study aimed to examine the extent to which improvements in physical performance are associated with reductions in pain. By analyzing the predictive role of upper- and lower-limb strength measures on post-intervention pain levels, this research sought to clarify the contribution of functional and muscular adaptations to pain modulation and overall well-being in this clinical population.

The novelty of the present study lies in the implementation of a long-term structured resistance training program and in the comprehensive evaluation of the relationship between functional performance and pain in postmenopausal women with reduced bone density. Unlike many previous investigations focusing on short-term interventions or isolated outcomes, the present study provides an integrated analysis of physical function and pain-related changes following prolonged exercise training.

2. Materials and Methods

A controlled intervention study was conducted in a sample of 39 postmenopausal women diagnosed with osteopenia or osteoporosis, allocated to either an exercise group (n = 20; mean age 56 ± 2.9 years) who participated in a supervised strength training program or a control group (n = 20; mean age 56 ± 2.9 years) who did not engage in structured exercise or other regular physical activity. Participants were assigned to the exercise group or control group using a nonrandomized allocation procedure based on individual preference and availability. Outcome assessments were conducted under standardized conditions, and assessors were not blinded to group assignment during baseline and post-intervention measurements. Inclusion criteria required participants to be sedentary, non-smokers. Exclusion criteria included ongoing corticosteroid treatment. Sample size for the MANOVA was calculated with G*Power 3.1.9, considering a medium effect size ($f^2(V) = 0.5$), $\alpha = 0.05$, and power = 0.80. For a design including two groups, the software suggested a minimum of 32 participants. Bone mineral density was assessed using DEXA. All participants received daily supplementation with 0.5 μg alfacalcidol. The strength training program lasted 12 months, with sessions conducted twice weekly on non-consecutive days to allow adequate recovery. The first weekly session included hip adduction, hip abduction, hip extension, triceps dips, hip flexion, and back extension, all performed on machines from seated or standing position. Each exercise consisted of 2 sets of 12 repetitions (6 repetitions at 70% of one-repetition maximum [1RM] and 6 repetitions at 50% 1RM). The second weekly session targeted biceps (Scott bench curl), quadriceps and hamstrings (leg press, bodyweight squats, leg curls from prone position, leg extension from seated position), and back muscles (seated machine row). Rest periods between sets were 90 seconds. Participants were tested for 1RM in the second week to determine appropriate exercise intensity, with monthly reassessments to adjust load for subsequent weeks. Intensities of 70% and 50% 1RM were chosen to provide sufficient stimulus while minimizing excessive load on the hip and knee joints, reducing the risk of joint cartilage damage or osteoarthritis. All exercises, along with the muscle groups involved, images and details are presented in a dedicated book chapter [13]. The hip adductor movement in sitting is carried out using a dedicated apparatus where the legs begin separated at roughly a 45° angle and rest against the pads. By gripping the side bars for balance, the participant draws the legs inward and then slowly moves them back to the initial arrangement. For seated hip abductor work, a similar device is used, but the legs start close together on the pads. From this posture, the individual presses the thighs outward to about 40–45° before returning under control to the beginning position. Hip extension in standing is executed while the person balances on one limb, with the other leg suspended free. The torso leans slightly forward, the arms reach ahead, and the hands hold the support bars with a neutral hand position. Load is applied to the upper rear portion of the moving thigh. The participant drives the leg backward with the knee straight and then comes back to the start. The triceps dip action is completed on a machine with the user sitting tall and maintaining an upright spine. The elbows begin bent near 90°, and the upper arms are positioned laterally. Holding the grips with palms facing downward, the person presses by straightening the elbows and bringing the arms inward until near full extension, followed by a slow return. Single-leg hip flexion while standing is performed while supporting body weight on one leg as the other remains free. The torso stays vertical, the arms extend forward, and the handles are held neutrally. Resistance is attached to the front upper region of the working thigh. The subject lifts the thigh while bending the knee to about 90°, then lowers it back. Seated back extension uses a machine where the feet rest on a platform and the hands grasp side grips. The spine starts slightly rounded. By pushing through the legs, the person straightens the trunk against resistance until nearly level with the floor, then gradually returns. Elbow flexion on a Scott bench is done in sitting with the feet flat and knees bent. The torso remains upright while the back portion of the upper arms rests on the pad. Beginning with straight elbows and palms facing upward on the bar, the lifter bends the arms to roughly 90° and then lowers to the start. Lower-limb pressing on the horizontal sled begins in a seated posture with the feet placed parallel and shoulder-width on the platform and the knees near a right angle. The hands secure the side handles and the back stays against the support. From here, the legs push the platform away and then return smoothly. The squat movement starts from standing with the feet spaced apart in front of a bench or chair. Toes face forward, the arms cross over the chest, posture stays tall, and vision remains ahead. The participant lowers until the thighs become level with the floor (about 90° at the knees) and then rises again. During prone leg curls, the individual lies face-down on the device with the thighs supported and the legs straight, holding the side grips. Load is positioned near the lower calves. The knees bend until about a right angle and then extend back to the starting alignment. For seated knee extension, the person sits upright with the knees initially bent to 90° and resistance placed on the lower part of the legs. The movement consists of straightening the knees until the legs approach horizontal, followed by a controlled descent. In the machine-based horizontal arm opening task, the user sits tall with the chest against a pad and the hands holding the grips with palms down. From this setup, the arms move outward across the body plane while the elbows bend, bringing the hands toward abdominal level, and then return to the original posture. The study was conducted in accord ance with the Declaration of Helsinki. The health-related quality of life of participants was assessed using the QUALEFFO-41 questionnaire. The QUALEFFO-41 consists of 41 items structured into distinct sections evaluating pain (5 questions), activities of daily living (ADL; 4 questions), household tasks (House Jobs; 5 questions), mobility (8 questions), leisure activities (7 questions), general health perception (3 questions), and mental health (9 questions), facilitating a multidimensional assessment of HRQoL in this clinical population. Higher total and domain score values on the QUALEFFO-41 indicate poorer quality of life, with the scoring algorithm transforming raw responses to a 0–100 scale to enable comparison across domains and individuals. Physical performance was evaluated through a battery of well-established field tests that target major functional capabilities relevant to aging and frailty. Lower body strength and functional mobility were measured using the 30-second Chair Stand test, in which participants rise from a seated position and return to sitting repeatedly for 30 seconds, capturing the number of full stands completed as an index of lower extremity muscle performance. This test is widely employed in older adult research to assess leg strength and endurance and is part of validated functional fitness batteries [14]. Upper body muscular strength and endurance were assessed via the 30-second Arm Curl test, a standardized protocol in which seated participants perform as many biceps curls as possible within 30 seconds while holding a defined weight, providing an objective measure of upper limb muscular function. Additionally, handgrip strength was measured for both the dominant and non-dominant hand using a calibrated hand dynamometer, a reliable indicator of overall muscle strength and physical function that has been correlated with a range of clinical and functional outcomes in aging populations. Statistical analyses were conducted using SPSS v. 26. The level of significance was set at $p < .05$, and all tests were two-tailed. All variables were initially examined descriptively (means, standard deviations, and confidence intervals) prior to conducting inferential analyses. In the first step, the Shapiro–Wilk test was used to assess the distribution of scores. Paired samples t-tests were performed to determine within-group differences between baseline (pre) and post-intervention (post) measurements. When differences reached statistical significance ($p < .05$), Cohen's d was reported as a measure of effect size. To evaluate the effects of the intervention between groups across the set of dependent variables, a Multivariate Analysis of Variance (MANOVA) was conducted with the between-subjects factor Group (Exercise vs. Control). Values of F, p, and partial eta squared (η^2_p) were reported. When the multivariate model indicated significant differences, univariate follow-up analyses (one-way ANOVA) were performed for each variable to identify the specific components affected by the intervention. To examine the influence of physical performance on pain levels, a multiple linear regression analysis was conducted, with pain as the dependent variable and physical performance indicators as independent variables, including the Chair Stand Test, Arm Curl Test, dominant handgrip strength, and non-dominant handgrip strength. The regression model was used to determine whether these physical performance variables significantly predicted pain and to estimate the contribution of each independent variable to pain variability through regression coefficients and the coefficient of determination (R^2). Finally, Pearson correlation analysis was applied to explore bivariate relationships between physical performance and pain. The correlation coefficient (r) was used to evaluate the direction and strength of linear associations among the variables investigated.

3. Results

The multivariate MANOVA analysis showed no significant differences between groups across the dependent variables, Wilks' $\Lambda = .542$, $F(16, 12) = 0.635$, $p = .805$, $\eta^2 = .458$ (see table 1).

Table 1. Baseline Characteristics and Between-Group Comparisons for Control and Exercise Groups Across Study Variables

Variable	Ex	C	F	p
Height	160.7 (6.10)	159.3 (4.6)	3.90	.57
Age	56.20 (2.9)	56.4 (2.1)	0.32	.56
Weight	65.7 (6.62)	64.2 (7.4)	1.20	.51
BMD total hip	0.864 (0.069)	0.887 (0.095)	0.75	.39
BMD total spine	0.786 (0.042)	0.777 (0.057)	0.34	.56
Arm Curl	20.85 (1.66)	20.89 (1.91)	0.06	.94
Chair Stand	18.30 (1.03)	18.63 (1.74)	0.53	.47
Handgrip dominant	29.10 (4.20)	27.63 (3.18)	1.50	.23
Handgrip non-dominant	28.00 (5.01)	26.21 (3.47)	1.67	.21
Pain	53.00 (17.27)	53.42 (13.34)	0.07	.93
ADL	12.50 (6.08)	10.86 (4.08)	0.97	.33
House Job	10.33 (2.97)	8.16 (3.80)	2.10	.16
Mobility	9.75 (3.02)	11.02 (3.66)	0.24	.63
Leisure	62.21 (6.28)	62.76 (2.93)	0.12	.73
Health	56.25 (8.92)	55.70 (8.36)	0.04	.84
Mental	47.50 (8.92)	43.57 (6.42)	2.48	.12

The MANOVA revealed a strong multivariate effect of the physical intervention, indicating that the exercise group differed significantly from the control group at post-test across the 11 evaluated variables, Pillai's Trace = .872, $F(11, 27) = 16.78$, $p < .001$, $\eta^2_p = .872$, indicating that 87% of the combined variance in outcomes was explained by group membership. Participants in the exercise group demonstrated superior post-intervention performance on the Arm Curl test (M = 22.80, SD = 1.51) compared to the control group (M = 20.63, SD = 1.64). The difference was statistically significant, $F(1, 27) = 18.50$, $p < .001$, $\eta^2_p = .333$. Relative progress within the exercise group was +7.9%, whereas the control group showed a decline of -1.8%, resulting in a between-group difference in progress of +9.7%. These results indicate a notable improvement in upper-arm muscle strength attributable to the exercise program. Performance on the Chair Stand test was also higher in the exercise group (M = 20.45, SD = 1.27) than in the control group (M = 18.37, SD = 1.71), $F(1, 27) = 18.74$, $p < .001$, $\eta^2_p = .336$. Within-group progress for the exercise group was +11.1%, while the control group showed a decrease of -2.6%, yielding a between-group difference in progress of +13.7% (see table 2).

Table 2. Comparison of Percent Changes and ANOVA Results Between Exercise and Control Groups Across Variables

Variable	Exercise	Δ%	Control	% Δ	F	*p*	η^2_p
Arm Curl	22.80 (1.51)	7.9%	20.63 (1.64)	-1.8%	18.50	**<.001**	0.333
Chair Stand	20.45 (1.28)	11.1%	18.37 (1.71)	-2.6%	18.74	**<.001**	0.336
Handgrip-D	31.10 (3.87)	4.8%	27.16 (3.15)	-1.2%	12.12	**.001**	0.247
Handgrip-ND	29.40 (4.63)	3.3%	25.32 (3.28)	-1.8%	10.01	**.003**	0.213
Pain	32.00 (6.16)	-34.3%	50.00 (8.82)	-1.4%	55.10	**<.001**	0.598
ADL	7.81 (3.44)	-37.5%	13.16 (4.61)	17.9%	16.97	**<.001**	0.314
House Job	6.50 (2.35)	-37.1%	10.00 (3.73)	16.7%	12.44	**.001**	0.252
Mobility	9.44 (2.88)	3.0%	11.68 (3.02)	24.6%	5.62	**.023**	0.132
Leisure	53.91 (7.98)	-13.5%	60.02 (4.43)	-5.4%	8.61	**.006**	0.189
Health	35.00 (7.45)	-38.8%	51.31 (9.73)	-12.0%	34.78	**<.001**	0.485
Mental	30.84 (6.17)	-32.6%	41.38 (9.53)	-1.2%	16.98	**<.001**	0.315

Note. Δ% = Percent Change; F = F-value from ANOVA; *p* = Significance level; η^2_p = Partial Eta Squared (effect size).

This suggests substantial gains in lower-limb strength and functional mobility following the intervention. Dominant handgrip strength was significantly higher in the exercise group (M = 31.10, SD = 3.86) compared to the control group (M = 27.16, SD = 3.15), $F(1, 27) = 12.12$, $p = .001$, $\eta^2_p = .247$. Relative progress in the exercise group was +4.8%, whereas the control group decreased by -1.2%, resulting in a between-group difference of +6.0%, indicating a clear increase in muscular strength. Similarly, the exercise group outperformed the control group on non-dominant handgrip strength (M = 29.40, SD = 4.63 vs. M = 25.32, SD = 3.28), $F(1, 27) = 10.01$, $p = .003$, $\eta^2_p = .213$. Progress in the exercise group was +3.3%, while the control group declined by -1.8%, yielding a between-group difference of +5.1%, indicating a significant gain in non-dominant hand strength. The exercise group also showed a significant reduction in pain (M = 32.00, SD = 6.16) compared to the control group (M = 50.00, SD = 8.82), $F(1, 27) = 55.10$, $p < .001$, $\eta^2_p = .598$. Relative change in the exercise group was -34.3%, while the control group changed by -1.4%, resulting in a between-group difference of -32.9%, the largest observed effect, indicating a substantial pain reduction attributable to the exercise program. Activities of daily living (ADL) improved significantly in the exercise group (M = 7.81, SD = 3.44) compared to the control group (M = 13.16, SD = 4.61), $F(1, 27) = 16.97$, $p < .001$, $\eta^2_p = .314$. Relative progress was -37.5% in the exercise group and +17.9% in the control group, resulting in a between-group difference of -55.4%, highlighting a marked improvement in functional independence due to the intervention. The exercise group also scored better on house-related tasks (M = 6.50, SD = 2.35) compared to the control group (M = 10.00, SD = 3.73), $F(1, 27) = 12.44$, p = .001, $\eta^2_p = .252$, power = .93. Progress was -37.1% in the exercise group versus +16.7% in the control group, a between-group difference of -53.8%, indicating a clear benefit of exercise on household functional capacity. Overall mobility was higher in the exercise group (M = 9.44, SD = 2.88) than in the control group (M = 11.68, SD = 3.02), $F(1, 27) = 5.62$, $p = .023$, $\eta^2_p = .132$. Relative progress was +3.0% in the exercise group and +24.5% in the control group, yielding a between-group difference of -21.5%, indicating a modest improvement in mobility for the exercise group, whereas the control group showed a decline. Although higher scores indicate lower performance, the exercise group achieved better outcomes on social activities (M = 53.91, SD = 7.98) compared to the control group (M = 60.02, SD = 4.43), $F(1, 27) = 8.61$, $p = .006$, $\eta^2_p = .189$. Relative progress was -13.5% in the exercise group and -5.4% in the control group, with a between-group difference of -8.1%, indicating greater improvement in the exercise group. Participants in the exercise group reported better perceived health (M = 34.99, SD = 7.45) compared to the control group (M = 51.31, SD = 9.73), $F(1, 27) = 34.78$, $p < .001$, $\eta^2_p = .485$. Relative progress was -38.8% in the exercise group and -12.1% in the control group, resulting in a between-group difference of -26.7%, highlighting a strong effect of the intervention on perceived health. The exercise group also scored better on mental health (M = 30.83, SD = 6.17) compared to the control group (M = 41.37, SD = 9.53), $F(1, 27) = 16.98$, $p < .001$, $\eta^2_p = .315$. Relative progress was -32.6% in the exercise group and -1.2% in the control group, a between-group difference of -31.4%, indicating a significant improvement in mental well-being following the exercise program.

Participants in the exercise group showed a significant increase in Arm Curl performance (20.85 ± 1.66 vs. 22.80 ± 1.51), $t(19) = -22.132$, $p < .001$, d = 4.95, 95% CI [-2.134, -1.766], corresponding to an approximate 9.4% increase in arm muscle strength. This represents a clear and significant improvement, demonstrating the positive effect of the exercise program. In contrast, no significant difference was observed between pre- and post-test Arm Curl scores in the control group, $t(18) = 1.756$, $p = .096$, 95% CI [-0.052, 0.578]. The pre-intervention mean was 20.89 (SD = 1.91) and the post-intervention mean was 20.63 (SD = 1.64), reflecting a decrease in arm strength of approximately 1.2%. The between-group percentage difference was 10.6%, indicating a superior increase in upper limb muscle strength in the exercise group (see table 3).

Table 3. Intra-group Pre–Post Comparisons of Variables with Percent Change, t-Test, and 95% Confidence Intervals

Variable	G.	Pre	Post	Δ %	*t*	*p*	95% CI
Arm Curl	Ex	20.85 (1.66)	22.80 (1.51)	+9.4	-22.13	**<.001**	[-2.134, -1.766]
	C	20.89 (1.91)	20.63 (1.64)	-1.2	1.756	.096	[-0.052, 0.578]
Chair Stand	Ex	18.30 (1.03)	20.45 (1.28)	+11.7	-19.65	**<.001**	[-2.379, -1.921]
	C	18.63 (1.74)	18.37 (1.71)	-1.4	1.564	.135	[-0.090, 0.617]
HG-D	Ex	29.10 (4.20)	31.10 (3.87)	+6.9	-7.368	**<.001**	[-2.568, -1.432]
	C	27.63 (3.18)	27.16 (3.15)	-1.7	2.282	**.035**	[0.038, 0.910]
HG-ND	Ex	28.00 (5.01)	29.40 (4.63)	+5.0	-5.272	**<.001**	[-1.956, -0.844]
	C	26.21 (3.47)	25.32 (3.28)	-3.4	5.288	**<.001**	[0.539, 1.250]
Pain	Ex	53.00 (17.27)	32.00 (6.16)	-39.6	6.116	**<.001**	[13.813, 28.187]
	C	53.42 (13.34)	50.00 (8.82)	-6.4	1.556	.137	[-1.197, 8.039]
ADL	Ex	12.50 (6.08)	7.81 (3.44)	-37.5	4.265	**<.001**	[2.387, 6.988]
	C	10.86 (4.08)	13.16 (4.61)	-14.9	-2.111	**.049**	[-4.595, -0.011]
House Job	Ex	9.75 (3.02)	6.50 (2.35)	-33.3	5.940	**<.001**	[2.105, 4.395]
	C	8.16 (3.80)	10.00 (3.73)	+22.6	-2.111	**.049**	[-3.676, -0.008]
Mobility	Ex	10.47 (3.41)	6.50 (2.35)	-9.8	1.774	.092	[-0.185, 2.239]
	C	11.02 (3.66)	11.68 (3.02)	+6.0	-0.961	.349	[-2.110, 0.786]
Leissure	Ex	62.21 (6.28)	53.91 (7.98)	-13.3	5.314	**<.001**	[5.033, 11.574]
	C	62.76 (2.93)	60.02 (4.43)	-4.4	2.541	**.020**	[0.475, 5.008]
Health	Ex	56.25 (8.92)	34.99 (7.45)	-37.8	9.240	**<.001**	[16.439, 26.067]
	C	55.70 (8.36)	51.31 (9.73)	-7.9	1.606	.126	[-1.351, 10.127]
Mental	Ex	47.50 (8.92)	30.83 (6.17)	-35.1	9.678	**<.001**	[13.061, 20.269]
	C	43.57 (6.42)	41.38 (9.53)	-5.0	1.528	.144	[-0.821, 5.205]

Note. HG = handgrip; Δ% = Percent Change.

Similarly, Chair Stand results indicated a significant increase in performance in the exercise group, $t(19) = -19.648$, $p < .001$, d = 4.39, 95% CI [-2.379, -1.921], with a pre-test value of 18.30 ± 1.03 and a post-test value of 20.45 ± 1.28, representing an approximate 11.7% improvement, reflecting significant gains in lower limb strength and functional mobility. In the control group, Chair Stand performance slightly decreased

(18.63 ± 1.74 vs. 18.37 ± 1.71), t(18) = 1.564, p = .135, 95% CI [-0.090, 0.617], corresponding to an approximate 1.4% decline, which was not statistically significant, indicating maintained lower limb strength and mobility. The between-group percentage difference was 13.1%, suggesting a more pronounced improvement in lower limb strength and endurance in the exercise group. Dominant handgrip strength increased significantly in the exercise group, t(19) = -7.368, p < .001, d = 1.65, 95% CI [-2.568, -1.432], with a pre-test mean of 29.10 ± 4.20 and a post-test mean of 31.10 ± 3.87, representing an approximate 6.9% improvement. This increase confirms the positive effect of the exercise program on muscle strength. In contrast, the control group showed a statistically significant decrease in dominant handgrip strength between pre-test (M = 27.63, SD = 3.18) and post-test (M = 27.16, SD = 3.15), t(18) = 2.282, p = .035, d = 0.52, 95% CI [0.038, 0.910], corresponding to a relative decrease of approximately 1.7%. Similarly, non-dominant handgrip strength increased significantly in the exercise group (28 ± 5.01 vs. 29.40 ± 4.63), t(19) = -5.272, p < .001, d = 1.18, 95% CI [-1.956, -0.844], representing an approximate 5% improvement. In the control group, non-dominant handgrip strength showed a more pronounced and statistically significant decrease (26 ± 2.1 vs. 25.32 ± 3.28), t(18) = 5.288, p < .001, d = 1.21, 95% CI [0.539, 1.250], corresponding to a 3.4% reduction in grip strength. In the exercise group, a significant reduction in pain was observed, t(19) = 6.116, p < .001, d = 1.37, 95% CI [13.813, 28.187], representing a decrease of approximately 39.6% (53 ± 17.27 vs. 32 ± 6.16), the largest effect among all variables analyzed, highlighting the clear benefits of the exercise program on pain. The difference between the two groups was 8.6% for the dominant hand and 8.4% for the non-dominant hand, both indicating clear advantages in favor of the exercise program (see figure 1).

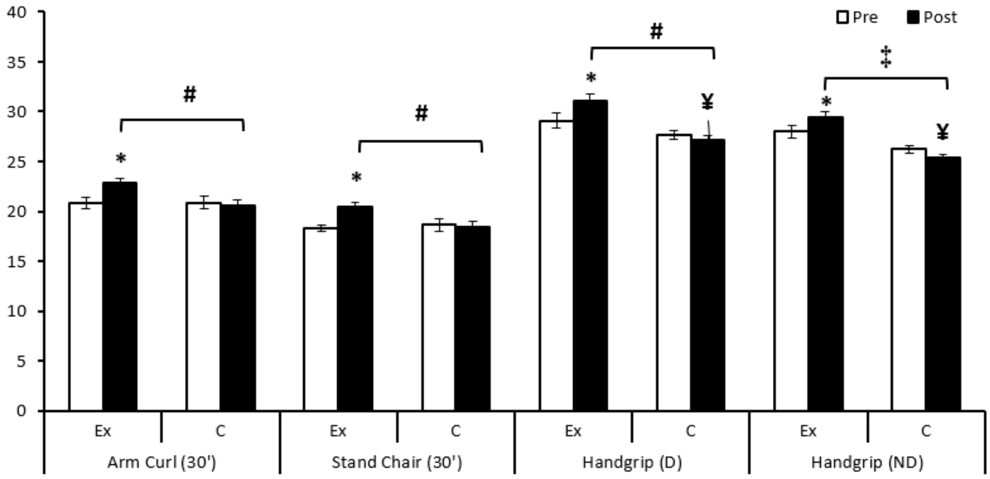

Figure 1. Pre and post-intervention performance in physical tests for exercise and control groups. * indicates p < .001 intra-group; ¥ indicates p < .05 intra-group; # indicates p < .001 inter-group; ‡ indicates p < .05 inter-group.

The difference between pre-test (53.42 ± 13.34) and post-test (50 ± 8.82) pain scores in the control group was not statistically significant, t(18) = 1.556, p = .137, 95% CI [-1.197, 8.039], suggesting an improvement of 6.5%. The difference between the two groups, expressed as the percentage change from pre- to post-test, was 33.2%, indicating a substantially greater reduction in pain in the exercise group compared to the control group (see figure 1). Activities of daily living (ADL) improved significantly in the exercise group (12.50 ± 6.08 vs. 7.81 ± 3.44), t(19) = 4.265, p < .001, d = 0.95, 95% CI [2.387, 6.988], indicating a reduction in difficulties of approximately 37.5%, reflecting increased functional independence. In the control group, a worsening was observed for the same variable (10.86 ± 4.08 vs. 13.16 ± 4.61), which was statistically significant, t(18) = -2.111, p = .049, d = 0.48, 95% CI [-4.595, -0.011], representing a decline of about 21.2% in functional independence, suggesting greater difficulty in performing daily activities compared to baseline. The difference between groups was

58.7%, representing the largest observed difference and highlighting the major impact of the strength training program on overall functional capacity (see figure 2).

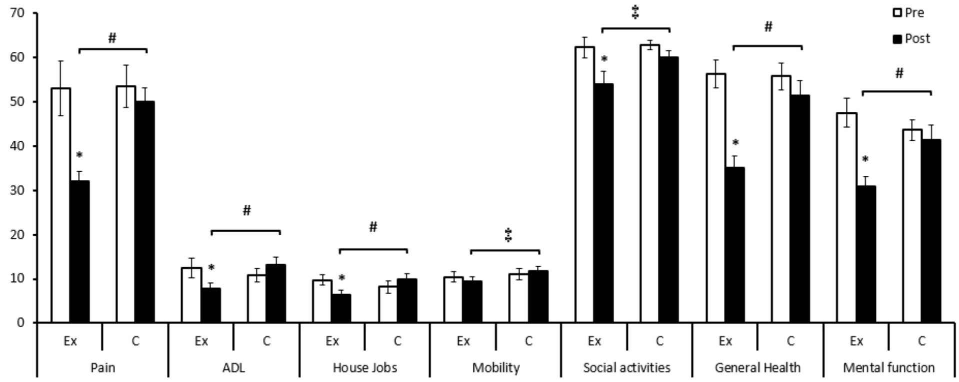

Figure 2. Pre- and post-intervention scores for quality of life domains in exercise and control groups. * indicates p < .001 intra-group; # indicates p < .001 inter-group; ‡ indicates p < .05 inter-group.

Participants in the exercise group showed a significant improvement (9.75 ± 3.02 vs. 6.50 ± 2.35), t(19) = 5.940, p < .001, d = 1.33, 95% CI [2.105, 4.395], corresponding to a reduction in difficulties of approximately 33.3%, suggesting better performance in household tasks. In contrast, the control group experienced a worsening of 22.6% for the same variable, which was statistically significant, t(18) = -2.111, p = .049, d = 0.48, 95% CI [-3.676, -0.008]. The percentage difference between the two groups was 55.9%, indicating a significantly greater improvement in the exercise group compared to the control group regarding the performance of daily household activities. Although the change was not statistically significant in the exercise group (10.47 ± 3.41 vs. 9.44 ± 2.88), t(19) = 1.774, p = .092, d = 0.40, 95% CI [-0.185, 2.239], indicating an increase of approximately 12.1%, there was still a trend toward improved overall mobility. In the control group, a 6% worsening was observed for this variable, but the difference was not statistically significant, t(18) = -0.961, p = .349, 95% CI [-2.110, 0.786]. The difference between groups was 15.8%, suggesting a moderate but clearly favorable improvement in the exercise group. Participants in the exercise group showed a significant reduction in scores (indicating better functioning) for the variable leisure activities (62.21 ± 6.28 vs. 53.91 ± 7.98), t(19) = 5.314, p < .001, d = 1.19, 95% CI [5.033, 11.574], representing an improvement of approximately 13.3% in recreational activities. The control group also showed an improvement for this variable of 4.4%, which was statistically significant, t(18) = 2.541, p = .020, d = 0.48, 95% CI [0.475, 5.008]. Since higher scores indicate poorer functioning, the decrease from the initial score (62.76 ± 2.93) to the final score (60.02 ± 4.43) actually represents an improvement. The percentage difference between groups was 8.9%, the smallest difference among all variables analyzed, indicating a positive but smaller, yet consistent, effect of the intervention. Regarding the health status variable, the exercise group showed a significant improvement (56.25 ± 8.92 vs. 35 ± 7.45), t(19) = 9.240, p < .001, d = 2.07, 95% CI [16.439, 26.067], representing an increase in perceived health of approximately 37.8%. In the control group, the difference between the initial (55.70 ± 8.36) and final scores (51.31 ± 9.73) was not statistically significant, t(18) = 1.606, p = .126, 95% CI [-1.351, 10.127], corresponding to an improvement of approximately 7.2% for this variable. The percentage difference between the Exercise and Control groups was 29.9%, suggesting a significantly better perception of health among participants who followed the exercise program (see figure 2). A significant improvement in mental health was also observed in the exercise group (47.5 ± 8.92 vs. 30.83 ± 6.17), t(19) = 9.678, p < .001, d = 2.16, 95% CI [13.061, 20.269], representing an increase in perceived mental well-being of approximately 35.1%. In the control group, although a 5% improvement was observed for the same variable, the difference was not statistically significant, t(18) = 1.528, p = .144, 95% CI [-0.821, 5.205]. The percentage difference between the two groups was 30.1%, indicating a substantial beneficial effect of the exercise program on the psychological components of well-being.

A multiple regression analysis was conducted to examine the extent to which post-intervention Chair Stand performance predicts post-intervention pain levels, after controlling for baseline pain and baseline Chair Stand performance. In the first block of the analysis, Pain_pre and ChairStand_pre were entered as predictors. This initial model was marginally non-significant, $F(2, 36) = 2.78$, $p = .075$, explaining 13.4% of the variance in post-intervention pain ($R^2 = .134$). This indicates that, prior to including post-intervention physical performance, baseline pain and physical performance contribute relatively little to explaining post-intervention pain. In the second step, ChairStand_post was added to the model, resulting in a significant increase in explained variance, $R^2 = .410$, $F(1, 35) = 31.43$, $p < .001$. The final model was significant and accounted for 54.4% of the variance in post-intervention pain ($R^2 = .544$). These results suggest that post-intervention Chair Stand performance is a strong and independent predictor of pain, beyond the influence of baseline pain levels. In practical terms, approximately 41% of the variance in post-intervention pain is explained solely by ChairStand_post performance. Moreover, the coefficient analysis indicates that for each additional repetition completed in the Chair Stand test at the end of the intervention, the post-intervention pain score decreases on average by 5.58 points, highlighting a clear inverse relationship between lower limb strength and perceived pain. A linear regression was conducted to examine the extent to which post-intervention Arm Curl performance predicts post-intervention pain, controlling for baseline pain. The model was significant in explaining the variation in post-intervention pain, $F(2, 37) = 25.53$, $p < .001$, $R^2 = .573$, adjusted $R^2 = .556$. This model suggests that approximately 57% of the variance in post-intervention pain can be explained by these two predictors combined. Examining the individual coefficients, Arm Curl peformance had a significant negative effect on post-intervention pain, $B = -4.499$, $SE = 0.890$, $\beta = -.726$, $t(37) = -5.053$, $p < .001$, 95% CI [-6.304, -2.693]. This indicates that, after controlling for baseline pain, a one-unit increase in post-intervention Arm Curl performance is associated with an average reduction of approximately 4.5 points in the post-intervention pain score. In contrast, pain (pre) was not a significant predictor in this model, $B = -0.034$, $SE = 0.111$, $\beta = -.044$, $t(37) = -0.304$, $p = .763$, 95% CI [-0.258, 0.191]. This suggests that, after including Arm Curl (post) in the model, baseline pain values no longer add significant explanatory power for post-intervention pain. The results indicate that arm muscle performance, as measured by post-intervention Arm Curl, is a strong and favorable predictor of pain reduction, even after controlling for baseline pain. This implies that improvements in arm strength have a direct and positive impact on reducing perceived pain. Another analysis was conducted to evaluate the extent to which dominant handgrip strength (post) and baseline pain predict post-intervention pain (post). The model was significant, explaining approximately 23% of the variance in post-intervention pain ($R^2 = 0.231$, $F(2, 37) = 5.52$, $p = .008$). Examining both standardized and unstandardized coefficients, baseline pain had a significant positive effect on post-intervention pain, $B = 0.235$, $SE = 0.104$, $\beta = 0.305$, $t(37) = 2.268$, $p = .029$, 95% CI [0.025, 0.445]. This result suggests that for each unit increase in baseline pain, post-intervention pain is expected to increase by approximately 0.24 units, assuming dominant handgrip strength remains constant. In contrast, post-intervention dominant handgrip strength had a significant negative effect on post-intervention pain, $B = -1.410$, $SE = 0.394$, $\beta = -0.481$, $t(37) = -3.582$, $p = .001$, 95% CI [-2.209, -0.612]. This result indicates that greater handgrip strength is associated with lower levels of pain after the intervention. The standardized beta suggests that dominant handgrip strength has a stronger effect than baseline pain on post-intervention pain ($\beta = -0.481$ vs. $\beta = 0.305$). In conclusion, this model demonstrates that post-intervention dominant handgrip strength significantly influences pain reduction, and controlling for baseline pain allows for a more precise estimation of this effect. A multiple linear regression was also conducted to investigate the extent to which post-intervention non-dominant handgrip strength and baseline pain predict post-intervention pain. The model was significant, explaining approximately 22% of the variance in post-intervention pain ($R^2 = 0.215$, $F(2, 37) = 5.05$, $p = .011$). Analyzing the coefficients, baseline pain had a significant positive effect on post-intervention pain, B = 0.253, SE = 0.106, β = 0.328, t(37) = 2.382, p = .023, 95% CI [0.038, 0.468]. This indicates that, holding non-dominant handgrip strength constant, each additional unit of baseline pain is associated with an increase of approximately 0.25 units in post-intervention pain. In contrast, post-intervention non-dominant handgrip strength had a significant negative effect on post-intervention pain, B = -1.146, SE = 0.362, β = -0.436, t(37) = -3.166, p = .003, 95% CI [-1.880, -0.412]. This suggests that participants with greater non-dominant handgrip strength reported lower levels of post-intervention pain. The standardized coefficient indicates that handgrip (non-dominant, post) had a stronger impact on post-intervention pain than baseline pain (β = -0.436 vs. β = 0.328). In conclusion, this model highlights that lower limb strength (measured by the Chair Stand test), arm strength (measured by Arm Curl), and handgrip strength (both dominant and non-dominant) significantly influence post-intervention pain levels, suggesting that improvements in muscle strength, including grip strength, can contribute to pain reduction. The results suggest that pain relief is driven by the overall combination of physical improvements. A strong and statistically significant negative correlation was identified between post-intervention Arm Curl scores and post-intervention pain, r(37) = −.70, p < .001, indicating that higher upper limb strength was associated with lower levels of pain. Post-intervention Chair Stand performance was significantly negatively correlated with post-intervention pain, r(37) = −.62, p < .001, suggesting that better lower limb functional performance is associated with lower pain levels. Post-intervention dominant handgrip strength showed a significant negative correlation with post-intervention pain, r(37) = −.52, p = .001. Non-dominant handgrip strength post-intervention was also significantly negatively correlated with post-intervention pain, r(37) = −.46, p = .003, indicating a moderate association between increased strength and pain reduction. verall, the descriptive results indicate improvements in physical performance and a clinically relevant reduction in pain following the intervention. The moderate-to-strong negative correlations between physical performance tests and pain suggest that enhancements in muscular and functional capacity are associated with lower pain levels, explaining approximately 30% to 50% of the shared variance among the analyzed variables.

4. Discussion

Clinical analyses in women with osteoporosis have shown that health-related quality of life (HRQoL) is closely linked to both pain and physical function, as measured by specific tests. Chronic post-fracture pain significantly affects the physical and social domains of quality of life (SF-36 and QUALEFFO-41), and declines in physical performance (mobility, balance, walking ability) contribute to this negative impact on QoL [15], [16]. Although not all interventions are specifically designed to target QoL, meta-analytic evidence indicates that exercise programs that improve muscle strength — including increases in 30-second Arm Curl, 30-second Chair Stand, and handgrip strength — lead to significant improvements in physical function and maintain or enhance mobility and independence, which in turn are associated with better perceived quality of life in older populations [17]. Some studies suggest that overall physical fitness in women with osteoporosis is lower compared to healthy individuals, and this functional decline is associated with a higher risk of falls and reduced mobility, factors that can negatively affect perceived quality of life in those affected [18]. This finding supports the use of functional tests (e.g., Chair Stand, Arm Curl, Handgrip) as indicators of physical performance that may also indirectly reflect QoL domains — including independence in daily activities and social participation. A cohort study conducted in older adults [19] showed a significant positive association between handgrip strength (HGS) and quality of life, regardless of sex, indicating that each 1 kg increase in HGS was correlated with a higher QoL score measured by the CASP-16 tool (0.24 in women and 0.18 in men). This suggests that loss of muscle strength can have a negative impact on well-being in older adults. This investigation explored how habitual movement levels, muscular capacity, body composition, and functional abilities relate to perceived well-being among older individuals exhibiting early or established frailty while living independently. Using validated instruments, multiple aspects of self-perceived well-being were examined alongside objective and self-reported measures of movement behavior, strength, muscle quantity, and functional tasks. Evidence from randomized controlled studies involving older adults with early or established frailty indicates that exercise-based interventions encompassing endurance activities, resistance exercises, balance training, flexibility work, or multimodal approaches yield meaningful health benefits. Across the reviewed trials, improvements were most consistently observed in functional abilities and force-generating capacity, alongside reductions in frailty severity. In contrast, gains in muscle tissue quantity were less frequently reported. Considerable variability was noted across studies with respect to training design, intensity, duration, assessment methods, and mode of program delivery [20]. Physical training is widely recognized as a non-pharmacological strategy capable of enhancing neuromuscular capacity and functional abilities, thereby contributing to the management of frailty in later life. Previous evidence syntheses have examined the influence of structured movement programs on functional outcomes such as force production, locomotion, postural control, and overall task performance. These analyses generally suggest that programs combining multiple exercise modalities yield superior functional benefits in vulnerable older populations. Nevertheless, uncertainty remains regarding the optimal configuration of training variables—including modality, dosage, intensity, duration, and long-term adherence—that maximizes and sustains these benefits. Evidence drawn from comprehensive reviews focusing on community-residing adults aged 60 years and older with early or established frailty demonstrates that exercise-based interventions, implemented either alone or alongside dietary strategies, are associated with meaningful improvements in functional outcomes. Most programs involved moderate weekly training frequencies over several months and predominantly emphasized combined approaches integrating resistance-based tasks with endurance, balance, and flexibility components. Such multimodal strategies were consistently linked to gains in strength, walking efficiency, stability, and global functional performance. Programs relying solely on resistance-focused activities also showed favorable effects, particularly for strength-related outcomes and mobility. In contrast, other exercise modalities have received limited investigation, preventing firm conclusions regarding their independent effectiveness. Overall, the available evidence supports the implementation of comprehensive, multi-domain exercise programs for frail and pre-frail older individuals. Future investigations should apply standardized frailty classifications and further explore alternative training modalities and combined lifestyle interventions to enable more precise and evidence-based exercise prescriptions [21]. Although not directly focused on QoL, research shows that handgrip strength is positively associated with bone mineral density (BMD) and a lower risk of fractures in postmenopausal women. This suggests that loss of muscle strength — reflected in tests such as handgrip or Arm Curl — may be linked to poorer clinical outcomes that indirectly affect QoL through physical inactivity and increased risk of complications [22], [23]. In a population-based study, performance on functional body tests (chair stand, timed up and go, handgrip) was positively correlated with multiple domains of physical quality of life, measured by the SF-36, in both adults and older adults, indicating that better functional performance translates into higher scores on the physical components of QoL [24]. Specifically, the 30-second chair stand test was associated with overall physical function and fewer disease-related symptoms in colorectal cancer patients, highlighting links between lower-limb muscular performance and relevant HRQoL dimensions [25]. A study of an active population found that poorer performance on chair stand and Arm Curl tests was associated with a higher risk of lower overall QoL, including both physical and social

HRQoL components, supporting and contextualizing observations of negative correlations between reduced muscle performance, pain, and functional limitations [26]. Additionally, the literature indicates that components such as physical activity level, balance, and walking speed (often included in functional test batteries) are strongly associated with at least certain QoL subscales in adults and older adults, emphasizing the importance of multifactorial assessments in understanding QoL [19]. Another study [27] provides evidence that engagement in movement-related behaviors is linked to perceived health status in later life. A randomized controlled trial [28] examined the effect of an exercise program on quality of life in postmenopausal women with osteoporosis. Participants were assigned to exercise or control groups without exercise for one year. The results showed significant improvements in pain, physical activity, social life, and perceived health status in the groups that participated in exercise, compared with those who did not exercise ($p < .0001$), while mental function did not show significant differences. Another systematic review of clinical studies in postmenopausal women with osteoporosis or osteopenia confirmed the positive effects of physical exercise on physical function, mobility, vitality, and overall quality of life. Exercise types ranged from Tai Chi, high-intensity aerobic exercise, progressive low-impact exercise, and Pilates, to closed-kinetic chain exercises, demonstrating overall efficacy in improving QoL [29]. Osteoporosis represents a significant public health concern, marked by reduced bone density and deterioration of bone structure, which can negatively affect daily functioning and well-being. In this cross-sectional study [30] comparing postmenopausal women with and without osteoporosis, participants with the condition reported lower overall quality of life, particularly in domains related to mobility and cognitive-emotional functioning. Physical activity levels, as assessed by standardized questionnaires, did not differ substantially between the two groups. However, among women with osteoporosis, higher engagement in physical activity was modestly associated with better perceived quality of life. These findings suggest that, while physical activity patterns may be similar regardless of bone health status, promoting greater activity among postmenopausal women with osteoporosis could help mitigate declines in well-being and enhance daily functioning. Analysis of data from a large community-based cohort of older adults indicates that osteoporosis is linked to lower physical aspects of quality of life, with a more pronounced effect in women. Among participants, women with osteoporosis reported reduced physical functioning compared with those without the condition, while mental health scores were largely unaffected. These findings suggest that skeletal fragility primarily compromises physical well-being rather than mental health in aging populations, and that women may be particularly vulnerable to these effects. Targeted strategies aimed at preserving or enhancing physical function in older adults with osteoporosis may therefore be critical for maintaining independence and promoting healthy aging [31]. Evidence from systematic review and meta-analysis indicates that postmenopausal women with osteoporosis experience lower health-related quality of life compared with their peers who have normal bone density. The presence of osteoporotic fractures further exacerbates this decline, particularly affecting physical functioning and overall well-being. Bone mineral density was positively correlated with quality-of-life outcomes, whereas the severity of fragility fractures showed a negative association, highlighting the impact of skeletal deterioration on daily life [32]. Findings from a large, long-term cohort study indicate that both self-reported and bone mineral density–confirmed osteoporosis are associated with lower health-related quality of life in adults aged 50 years and older, with women being particularly affected. Over a 10-year period, declines in most domains occurred regardless of osteoporosis status, although mental health components remained relatively stable. Fragility fractures were linked to additional reductions in quality of life and larger declines over time, emphasizing the cumulative impact of skeletal fragility. These results highlight the importance of evaluating and addressing quality of life in individuals with osteoporosis even before fractures occur, supporting the development of interventions aimed at preserving functional well-being across all stages of the disease [33]. A single-blinded randomized controlled trial evaluated the effects of a 12-week supervised multicomponent exercise program on older women with osteoporosis and prior vertebral fractures. The intervention targeted resistance, balance, and functional fitness, while the control group received standard care. Although habitual walking speed, the primary outcome, did not differ significantly between groups, notable improvements were observed in dynamic balance, upper- and lower-limb strength, and functional lower-body performance among participants in the exercise group. Additionally, fear of falling was reduced, reflecting increased confidence in mobility [34]. Kronhed et al. (2009) [35] examined the impact of supervised resistance training on quality of life in women aged 60–81 diagnosed with osteoporosis. Sixty-five participants were allocated to either an exercise group or a control group. The intervention involved 60-minute sessions twice weekly for four months, including a stationary bike warm-up, targeted strengthening of back and abdominal muscles, resistance exercises for upper and lower limbs, and stretching, with intensity gradually increased according to individual ability. Following the program, the exercise group demonstrated improvements in six domains of the SF-36, reflecting enhanced physical and psychological well-being. Madureira et al. (2010) investigated the effects of a 12-month program on quality of life in women aged 65 and older with osteoporosis. Participants were assigned to a balance training group (n = 30) or a control group (n = 30). The intervention consisted of weekly one-hour supervised sessions, including warm-up and stretching (15 minutes each), walking exercises (15 minutes), and dynamic and static balance exercises (30 minutes). Participants were also instructed to perform the same exercises at home at least three times per week for 30 minutes. At the end of the study, the exercise group showed significant improvements compared with the control group across all measured domains [36]. Küçükçakır et al. (2013) investigated the effects of a supervised Pilates program on quality of life in postmenopausal women aged 45–65 with osteoporosis. Participants were assigned to either a Pilates intervention group (n = 35) or a home exercise control group (n = 32). The intervention consisted of twice-weekly, one-hour supervised Pilates sessions for one year. The control group performed trunk extension exercises at home, three sets of 20 repetitions, over the same period. The intervention group showed significant improvements across all QUALEFFO-41 domains [37]. Oh et al. (2015) examined the effects of the same exercise program on quality of life in 66 women aged ≥65 years, comparing aquatic versus land-based training. Participants performed 60-minute sessions, three times per week for 10 weeks. Participants were assigned to either an aquatic exercise group (n = 34, 1.2 m deep pool) or a land-based exercise group (n = 32). No significant differences between groups were found in the domains of general health (63.07±14.47 vs. 57.94±13.93, $p = 0.34$) or social functioning (83.67±16.64 vs. 89.45±14.92, $p = 0.80$). However, the aquatic exercise group showed significantly greater improvements in physical functioning (87.20±17.37 vs. 65.46±22.62, $p < 0.001$), role limitations due to physical health (91.91±24.40 vs. 56.25±40.16, $p < 0.001$), pain (95.58±7.46 vs. 69.37±23.13, $p < 0.001$), vitality (94.55±8.90 vs. 62.34±16.79, $p < 0.001$), role limitations due to emotional problems (91.91±24.40 vs. 61.45±41.57, $p = 0.002$), and mental health (95.05±11.18 vs. 71.50±17.41, $p < 0.001$) [38]. Schröder et al. (2012) investigated the effects of two different exercise programs over a 3-month period. Participants were assigned to either a suspension training group (n = 23, mean age 69.7 ± 3.7 years) or a conventional exercise group performing the same program without suspension straps (n = 21, mean age 71.0 ± 6.1 years). The 30-minute exercise sessions, conducted twice weekly, included stepper exercises, strengthening for upper and lower limbs, balance exercises, and stretching/relaxation. Both groups showed improvements in quality of life, but the suspension training group demonstrated significant improvements compared to baseline in the domains of: pain (Δ% = -28.9, $p < 0.001$), physical function (Δ% = -31.3, $p = 0.001$), overall health perception (Δ% = -17.5, $p = 0.001$), mental function ($p = 0.017$). No significant changes were observed in social activities ($p = 0.73$), although a slight worsening of symptoms was reported [39]. Angın and colleagues (2015) evaluated the effects of a Thai-Chi exercise program on quality of life in postmenopausal women with osteoporosis over a six-month period. Participants were divided into an experimental group, consisting of 22 women with a mean age of 58.2 ± 5.5 years, and a control group, consisting of 19 women with a mean age of 55.9 ± 9.2 years. The experimental group attended 60-minute exercise sessions three times per week, which included Pilates exercises during the first six weeks, resistance exercises using Thera-Band between weeks 6 and 18, and resistance exercises using a Pilates/Gym-Ball between weeks 18 and 24. The experimental group showed significant improvements in all domains compared to baseline, including pain (77.09 ± 10.33 vs. 63.18 ± 12.30, $p < .001$), activities of daily living (89.28 ± 6.83 vs. 81.60 ± 13.79, $p = .003$), household chores (73.14 ± 11.72 vs. 62.27 ± 15.47, $p < .001$), mobility (84.43 ± 8.20 vs. 73.12 ± 13.22, $p < .001$), social activities (62.01 ± 12.22 vs. 39.98 ± 14.81, $p < .001$), overall health perception (52.05 ± 9.24 vs. 35.07 ± 12.83, $p < .001$), and mental function (60.20 ± 10.19 vs. 51.95 ± 10.09, $p < .001$). In the control group, symptoms worsened compared to baseline [40]. In 2013, Basat et al. examined the impact of different exercise modalities on life quality in 35 postmenopausal women divided into a resistance training group, a high-impact exercise group, and a non-exercising control group. All participants received identical daily supplementation of vitamin D (800 IU) and calcium (1200 mg). Over six months, those performing resistance exercises three times per week experienced a substantial enhancement in overall quality of life (Δ% = 24.6, $p < .001$), whereas the control group showed minimal improvement (Δ% = 3.7%). Between-group comparisons confirmed a statistically significant effect of the intervention ($p < .001$), demonstrating that resistance training can markedly improve well-being in this population [41]. In 2016, Evstigneeva and colleagues conducted a study to evaluate the effects of a resistance exercise program on quality of life in women with osteoporosis who had sustained vertebral fractures. The experimental group (mean age 70.7 ± 8.1 years; n = 40) participated in a 12-month resistance exercise program, performed twice weekly, while the control group (67.6 ± 7.0 years; n = 38) did not engage in any exercise program during the study period. Neither group received any pharmacological treatment during the intervention. The exercise program consisted of three parts: an 8-minute warm-up, a main session including isotonic and isometric exercises, and a 4-minute cool-down with diaphragmatic breathing exercises. At the end of the study, the experimental group showed improvements in the domains of pain (Δ% = 21.6), activities of daily living (Δ% = 15.4), domestic tasks (Δ% = 21.5), mobility (Δ% = 19.7), social activities (Δ% = 5.4), and overall health perception (Δ% = 8.5); only the mental function domain slightly worsened by 0.6% compared to baseline. Significant differences were observed between the two groups at the study's conclusion for all QUALEFFO-41 domains ($p < .001$) [42]. Peng et al. investigated the effects of a 12-month, twice-weekly, 40-minute exercise program on postmenopausal women. Seventy-eight participants (mean age 69.2 years) were allocated to either the exercise group or a control group maintaining usual activities. Quality of life was evaluated using the QUALEFFO-41, while balance and functional mobility were assessed with the Balance Master® System, the "timed up and go," and "sit-to-stand" tests. After one year, the exercise group demonstrated significantly better overall QUALEFFO-41 scores compared to controls, with notable improvements in pain, household and mobility functions, social engagement, and general health perception. Balance measures, including tandem walk and sway, as well as functional mobility tests, also showed significant gains in the exercise group [43]. Positive results regarding quality of life were also reported in the study conducted by Marchese and colleagues, although this study included only women with osteopenia. The participants were divided into an experimental group (mean age 64.09 ± 8.90 years; n = 11) and a control group (mean age 59.73 ± 1.19 years; n = 11). The intervention program lasted 12 months, with sessions held three times per week, each lasting 50 minutes [44]. In 2010, Silvia Tolomio and colleagues evaluated the effects of an 11-month resistance exercise program on bone mineral density and functional capacity in postmenopausal women with osteoporosis. During the first 11 weeks, the exercise sessions were conducted three times per week in a fitness room, after which the program was carried out twice per week in the fitness room and once per week in a pool. Each 60-minute session included exercises with dumbbells, steppers, medicine balls, resistance bands, and bodyweight exercises. The experimental group (mean age 62 ± 5.0 years; n = 58) demonstrated a 39% increase in the 30-second arm curl test with a 2.3 kg dumbbell, a 10.5% increase in right-hand grip strength, and a 9.6% increase in left-hand grip strength. In contrast, the control group (mean age 64 ± 5.3 years; n = 67) showed only a 12% improvement in the arm curl test, with decreases in dynamometer-measured grip strength of 4.5% for the right hand and 3.5% for the left hand [45]. In 2010, Akiko Kanemaru and colleagues reported statistically significant improvements in handgrip strength for both the right hand (Δ% = 11, p = .001) and the left hand (Δ% = 11.2, p = .05) in the experimental group (mean age 74.7 ± 6.7 years; n = 37) compared to the control group (mean age 74.3 ± 7.0 years; n = 32). The exercise program was home-based and lasted for 12 months, with participants in the experimental group being instructed on how to perform the exercises independently at home; the experimental group showed significant improvements only in the physical function domain (p = .05) [46]. In 2017, Wen and colleagues conducted a study on postmenopausal women with osteoporosis (mean age 57.5 ± 3.5 years; n = 24) and observed notable improvements after a 10-week resistance exercise program. Participants in the experimental group completed 90-minute sessions three times per week, with exercise intensity set at 75–85% of their estimated maximal heart rate. At the end of the intervention, the experimental group showed a 47% improvement in the 30-second Chair Stand test and a 42.9% improvement in the 30-second Arm Curl test, indicating significant gains in lower- and upper-body muscle strength [47]. A large-scale study conducted in a cohort of adults aged over 40 years demonstrated that reduced handgrip strength was strongly associated with poorer health-related quality of life among individuals with osteoporosis compared with their healthy counterparts. Notably, these disparities were consistently observed across all dimensions of quality of life. Consequently, the coexistence of osteoporosis and diminished handgrip strength was associated with a markedly greater impairment in overall quality of life relative to individuals with preserved handgrip strength or those without osteoporosis [48]. Andrea Di Blasio and colleagues conducted a study comparing two different resistance circuit training programs in postmenopausal women with osteoporosis (mean age 59.35 ± 3.65 years; n = 32). At the end of the intervention, both groups showed significant improvements in handgrip strength, measured by dynamometry (p = .004), as well as in the 30-second Arm Curl test (p < .001). One group followed a traditional resistance training program, while the other performed exercises using a circuit training method, but both approaches led to meaningful gains in upper-body strength [49]. A study conducted between June 2018 and May 2019 assessed quality of life and life satisfaction in 198 postmenopausal women over 50 years old, attending osteoporosis clinics in Lodz. Tools used included the QUALEFFO-41. Participants had a mean age of 72.3 years and a mean BMI of 25.7 kg/m^2. Overall, quality of life was rated as moderate, with a QUALEFFO-41 mean score of 40.3. Women who had lived with osteoporosis for 6–10 years reported the lowest life satisfaction, and longer disease duration was associated with a decline in overall quality of life [50]. A recent cross-sectional investigation assessing quality of life via the SF-36 instrument demonstrated that, beyond the presence of osteoporosis, both nutritional status and the integrity of bone microarchitecture were significantly associated with variations in QoL scores. These findings underscore the multifactorial nature of quality-of-life determinants, highlighting how intricate biological and physiological factors converge to shape the subjective well-being of postmenopausal women [51]. Individuals who are both frail and have a high fear of falling report a markedly greater deterioration in quality of life compared with those who are not frail and do not fear falling. This indicates that fear of falling can exacerbate the functional and psychological limitations associated with frailty, leading to a poorer overall perception of health. Additionally, the influence of factors such as advanced age, low daily physical activity, history of falls, and the presence of comorbidities underscores the multifactorial nature of quality of life among older women with osteoporosis [16]. In a study [18] conducted on a cohort of 262 women aged 60–65 years, including 135 participants with clinically diagnosed osteoporosis and 127 age-matched healthy controls, a comprehensive assessment of physical fitness and fall risk was performed using standardized functional evaluation tools. Physical fitness was examined through the Senior Fitness Test (SFT). The application of these instruments enabled a multidimensional analysis of functional capacity, balance, mobility, and postural stability in both groups. The findings demonstrated that women with osteoporosis exhibited significantly lower levels of physical fitness compared with healthy participants, with the most pronounced differences observed in measures of upper- and lower-body flexibility. These deficits may be interpreted as a consequence of osteoporotic-related musculoskeletal deterioration, including reduced joint mobility, muscle weakness, and adaptive movement patterns aimed at minimizing pain or fracture risk. Such functional limitations can negatively influence overall movement efficiency and compromise the ability to perform activities of daily living.

5. Limitations

Several limitations of the present study should be considered when interpreting the findings. First, the relatively small sample size may restrict the generalizability of the results to the broader population of postmenopausal women with osteopenia or osteoporosis. Future investigations including larger samples would be valuable for confirming the observed effects.

Second, although the intervention protocol was carefully standardized, individual differences in daily physical activity levels and lifestyle habits outside the supervised sessions were not strictly controlled and may have influenced the outcomes.

Another limitation is that the study focused primarily on functional performance and quality-of-life indicators without including additional physiological or biomechanical measures that could provide a more detailed understanding of the mechanisms underlying the observed improvements.

Finally, the duration of follow-up was limited to the intervention period, and therefore it remains unclear whether the observed benefits would be maintained over a longer time after the completion of the exercise program.

Despite these limitations, the present findings contribute to the growing evidence supporting the role of structured resistance training as an effective non-pharmacological approach for improving functional capacity and well-being in postmenopausal women with reduced bone density.

6. Conclusions

The 12-month resistance training program led to significant improvements in physical performance among postmenopausal women with osteoporosis, including increases in Arm Curl, Chair Stand, and handgrip strength (dominant and non-dominant). Pain levels were substantially reduced in the exercise group compared to controls, demonstrating a clinically meaningful effect of strength training on pain management. Health-related quality of life improved markedly in participants performing exercises, with significant benefits observed in ADL, housework, mobility, leisure activities, perceived general health, and mental well-being. Multiple regression analyses indicated that post-intervention performance in both upper- and lower-limb strength tests was a strong independent predictor of reduced pain, highlighting the direct impact of muscular improvements on pain perception. Negative correlations between physical performance and pain further suggest that gains in muscle function contribute to better overall quality of life. These findings reinforce the essential role of resistance exercise as a non-pharmacological intervention for postmenopausal osteoporosis, offering comprehensive benefits for functional capacity, independence in daily activities, and psychological well-being.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Figure S1: title; Table S1: title; Video S1: title.

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References

1. Carrasco-Catena, A.; Monllor-Tormos, A.; De Guevara, N.M.L.; García-Pérez, M.Á.; Cano, A. Postmenopausal Osteopo-rosis. In Menopause; Cano, A., Ed.; Springer Nature Switzerland: Cham, 2025; pp. 147–167 ISBN 978-3-031-83978-8.
2. Cunningham, C.; O' Sullivan, R.; Caserotti, P.; Tully, M.A. Consequences of Physical Inactivity in Older Adults: A System-atic Review of Reviews and Meta - analyses. Scandinavian Med Sci Sports 2020, 30, 816 - 827, doi:10.1111/sms.13616.
3. Bangsbo, J.; Blackwell, J.; Boraxbekk, C.-J.; Caserotti, P.; Dela, F.; Evans, A.B.; Jespersen, A.P.; Gliemann, L.; Kramer, A.F.; Lundbye-Jensen, J.; et al. Copenhagen Consensus Statement 2019: Physical Activity and Ageing. Br J Sports Med 2019, 53, 856–858, doi:10.1136/bjsports-2018-100451.
4. Sexton, B.P.; Taylor, N.F. To Sit or Not to Sit? A Systematic Review and Meta - analysis of Seated Exercise for Older Adults. Australas J Ageing 2019, 38, 15 - 27, doi:10.1111/ajag.12603.
5. Ikai, S.; Uchida, H.; Mizuno, Y.; Tani, H.; Nagaoka, M.; Tsunoda, K.; Mimura, M.; Suzuki, T. Effects of Chair Yoga Therapy on Physical Fitness in Patients with Psychiatric Disorders: A 12-Week Single-Blind Randomized Controlled Trial. Journal of Psychiatric Research 2017, 94, 194–201, doi:10.1016/j.jpsychires.2017.07.015.
6. Stubbs, B.; Brefka, S.; Denkinger, M.D. What Works to Prevent Falls in Community-Dwelling Older Adults? Umbrella Review of Meta-Analyses of Randomized Controlled Trials. Physical Therapy 2015, 95, 1095–1110, doi:10.2522/ptj.20140461.
7. Kumar, S.; Smith, C.; Clifton-Bligh, R.J.; Beck, B.R.; Girgis, C.M. Exercise for Postmenopausal Bone Health – Can We Raise the Bar? Curr Osteoporos Rep 2025, 23, 20, doi:10.1007/s11914-025-00912-7.
8. Moreira, L.D.F.; Oliveira, M.L.D.; Lirani-Galvão, A.P.; Marin-Mio, R.V.; Santos, R.N.D.; Lazaretti-Castro, M. Physical Exer-cise and Osteoporosis: Effects of Different Types of Exercises on Bone and Physical Function of Postmenopausal Women. Arq Bras Endocrinol Metab 2014, 58, 514–522, doi:10.1590/0004-2730000003374.
9. Nguyen, C.T.; Van Thai, C.; Hong, N.N.T.; Huu, T.D.; Elsheikh, R.; Alagbo, H.O.; Makram, A.M.; Huy, N.T. Clinical Mani-festations and Quality of Life of Postmenopausal Women with Severe Osteoporosis: A Cross-Sectional Study on the Viet-namese Population. BMC Women's Health 2025, 25, 509, doi:10.1186/s12905-025-04056-9.
10. Meyer, F.; König, H.-H.; Hajek, A. Osteoporosis, Fear of Falling, and Restrictions in Daily Living. Evidence From a Na-tionally Representative Sample of Community-Dwelling Older Adults. Front. Endocrinol. 2019, 10, 646, doi:10.3389/fendo.2019.00646.
11. Rico, C.L.V.; Curcio, C.L. Fear of Falling and Environmental Factors: A Scoping Review. Ann Geriatr Med Res 2022, 26, 83–93, doi:10.4235/agmr.22.0016.
12. Hamed, K.; Roaldsen, K.S.; Halvarsson, A. "Fear of Falling Serves as Protection and Signifies Potential Danger": A Qualita-tive Study to Conceptualise the Phrase "Fear of Falling" in Women with Osteoporosis. Osteoporos Int 2021, 32, 2563–2570, doi:10.1007/s00198-021-06047-6.
13. Holubiac, I. Ștefan Strength Training Program for Postmenopausal Women with Osteoporosis. In Biomedical Engineering Applications for People with Disabilities and the Elderly in the COVID-19 Pandemic and Beyond; Elsevier, 2022; pp. 185–196 ISBN 978-0-323-85174-9.
14. Fishleder, S.; Petrescu-Prahova, M.; Harris, J.R.; Leroux, B.; Bennett, K.; Helfrich, C.D.; Kohn, M.; Hannon, P. Predictors of Improvement in Physical Function in Older Adults in an Evidence-Based Physical Activity Program (EnhanceFitness). Journal of Geriatric Physical Therapy 2019, 42, 230–242, doi:10.1519/JPT.0000000000000202.

15. Stanghelle, B.; Bentzen, H.; Giangregorio, L.; Pripp, A.H.; Skelton, D.A.; Bergland, A. Physical Fitness in Older Women with Osteoporosis and Vertebral Fracture after a Resistance and Balance Exercise Programme: 3-Month Post-Intervention Follow-up of a Randomised Controlled Trial. BMC Musculoskelet Disord 2020, 21, 471, doi:10.1186/s12891-020-03495-9.
16. Zhang, L.; Liu, L.; Chen, C.; Tan, Y.; Fan, X.; Wei, L.; Miao, Y.; Luo, X. The Impact of Frailty and Fear of Falling on Health-Related Quality of Life in Older Adults with Osteoporosis: A Cross-Sectional Study. BMC Geriatr 2025, 25, 938, doi:10.1186/s12877-025-06625-x.
17. Klempel, N.; Blackburn, N.E.; McMullan, I.L.; Wilson, J.J.; Smith, L.; Cunningham, C.; O'Sullivan, R.; Caserotti, P.; Tully, M.A. The Effect of Chair-Based Exercise on Physical Function in Older Adults: A Systematic Review and Meta-Analysis. IJERPH 2021, 18, 1902, doi:10.3390/ijerph18041902.
18. Babiuch, A.S.; Oestervemb, K.; Lipińska, A.; Stańczak, M.L.; Cholewa, M.; Makulec, K.; Nowakowska, K.; Derengowska, M.H. Differences in the Level of Physical Fitness and Mobility among Older Women with Osteoporosis and Healthy Women—Cross-Sectional Study. Sci Rep 2021, 11, 14179, doi:10.1038/s41598-021-93483-3.
19. Haider, S.; Luger, E.; Kapan, A.; Titze, S.; Lackinger, C.; Schindler, K.E.; Dorner, T.E. Associations between Daily Physical Activity, Handgrip Strength, Muscle Mass, Physical Performance and Quality of Life in Prefrail and Frail Community-Dwelling Older Adults. Qual Life Res 2016, 25, 3129–3138, doi:10.1007/s11136-016-1349-8.
20. Haider, S.; Grabovac, I.; Dorner, T.E. Effects of Physical Activity Interventions in Frail and Prefrail Community-Dwelling People on Frailty Status, Muscle Strength, Physical Performance and Muscle Mass—a Narrative Review. Wien Klin Woch-enschr 2019, 131, 244–254, doi:10.1007/s00508-019-1484-7.
21. Jadczak, A.D.; Makwana, N.; Luscombe-Marsh, N.; Visvanathan, R.; Schultz, T.J. Effectiveness of Exercise Interventions on Physical Function in Community-Dwelling Frail Older People: An Umbrella Review of Systematic Reviews. JBI Database of Systematic Reviews and Implementation Reports 2018, 16, 752–775, doi:10.11124/JBISRIR-2017-003551.
22. Wu, N.; Li, X.; Mu, S.; Fu, Q.; Ba, G. Handgrip Strength Is Positively Associated with Bone Mineral Density in Middle and Aged Adults: Results from NHANES 2013–2014. Arch Osteoporos 2021, 16, 121, doi:10.1007/s11657-021-00938-1.
23. Huang, S.-G.; Lee, R.-P.; Yao, T.-K.; Wang, J.-H.; Wu, W.-T.; Yeh, K.-T. Correlation Between Handgrip Strength and Bone Density and Fragility Fracture Risk Among Older Adults: A Cross-Sectional Study. Journal of Nursing Research 2025, 33, e375, doi:10.1097/jnr.0000000000000656.
24. Alegría-Molina, A.; Artigas-Arias, M.; Bascour-Sandoval, C.; Soto-Rodríguez, F.J.; Muñoz-Poblete, C.; Marzuca-Nassr, G.N. Calidad de Vida, Nivel de Actividad Física y Pruebas Funcionales En Personas Adultas y Mayores Laboralmente Activas. Rev. méd. Chile 2022, 150, 1625–1632, doi:10.4067/s0034-98872022001201625.
25. Soares-Miranda, L.; Lucia, A.; Silva, M.; Peixoto, A.; Ramalho, R.; Da Silva, P.C.; Mota, J.; Macedo, G.; Abreu, S. Physical Fitness and Health-Related Quality of Life in Patients with Colorectal Cancer. Int J Sports Med 2021, 42, 924–929, doi:10.1055/a-1342-7347.
26. Valdés-Badilla, P.; Alarcón-Rivera, M.; Hernandez-Martinez, J.; Herrera-Valenzuela, T.; Branco, B.H.M.; Núñez-Espinosa, C.; Guzmán-Muñoz, E. Factors Associated with Poor Health-Related Quality of Life in Physically Active Older People. IJERPH 2022, 19, 13799, doi:10.3390/ijerph192113799.
27. Liao, Y.-H.; Kao, T.-W.; Peng, T.-C.; Chang, Y.-W. Gender Differences in the Association between Physical Activity and Health-Related Quality of Life among Community-Dwelling Elders. Aging Clin Exp Res 2021, 33, 901–908, doi:10.1007/s40520-020-01597-x.
28. Koevska, V.; Nikolikj-Dimitrova, E.; Mitrevska, B.; Gjeracaroska-Savevska, C.; Gocevska, M.; Kalcovska, B. Effect of Exer-cises on Quality of Life in Patients with Postmenopausal Osteoporosis – Randomized Trial. Open Access Maced J Med Sci 2019, 7, 1160–1165, doi:10.3889/oamjms.2019.271.
29. Anupama, D.S.; Norohna, J.A.; Acharya, K.Kv.; Ravishankar; George, A. Effect of Exercise on Bone Mineral Density and Quality of Life among Postmenopausal Women with Osteoporosis without Fracture: A Systematic Review. International Journal of Orthopaedic and Trauma Nursing 2020, 39, 100796, doi:10.1016/j.ijotn.2020.100796.
30. Erol, E.; Okan, F.; Okan, S. Comparison of Physical Activity Levels and Quality of Life of Postmenoposal Women with and Without Osteoporosis. Tod 2023, 29, 53–58, doi:10.4274/tod.galenos.2022.48344.
31. Zarinfar, Y.; Panahi, N.; Hosseinpour, M.; Sedokani, A.; Hajivalizadeh, S.; Nabipour, I.; Larijani, B.; Fahimfar, N.; Ostovar, A. The Association between Osteoporosis and Quality of Life among Older Adults in Southern Iran: Findings from the Bu-shehr Elderly Health Program. BMC Geriatr 2024, 24, 766, doi:10.1186/s12877-024-05348-9.
32. Gao, S.; Zhao, Y. Quality of Life in Postmenopausal Women with Osteoporosis: A Systematic Review and Meta-Analysis. Qual Life Res 2023, 32, 1551–1565, doi:10.1007/s11136-022-03281-1.
33. The CaMos Research Group; Hopman, W.M.; Berger, C.; Joseph, L.; Morin, S.N.; Towheed, T.; Anastassiades, T.; Adachi, J.D.; Hanley, D.A.; Prior, J.C.; et al. Longitudinal Assessment of Health-Related Quality of Life in Osteoporosis: Data from the Population-Based Canadian Multicentre Osteoporosis Study. Osteoporos Int 2019, 30, 1635–1644, doi:10.1007/s00198-019-05000-y.
34. Stanghelle, B.; Bentzen, H.; Giangregorio, L.; Pripp, A.H.; Skelton, D.A.; Bergland, A. Effects of a Resistance and Balance Exercise Programme on Physical Fitness, Health-Related Quality of Life and Fear of Falling in Older Women with Osteo-porosis and Vertebral Fracture: A Randomized Controlled Trial. Osteoporos Int 2020, 31, 1069–1078, doi:10.1007/s00198-019-05256-4.
35. Grahn Kronhed, A.-C.; Hallberg, I.; Ödkvist, L.; Möller, M. Effect of Training on Health-Related Quality of Life, Pain and Falls in Osteoporotic Women. Advances in Physiotherapy 2009, 11, 154–165, doi:10.1080/14038190902896659.
36. Madureira, M.M.; Bonfá, E.; Takayama, L.; Pereira, R.M.R. A 12-Month Randomized Controlled Trial of Balance Training in Elderly Women with Osteoporosis: Improvement of Quality of Life. Maturitas 2010, 66, 206–211, doi:10.1016/j.maturitas.2010.03.009.

37. Küçükçakır, N.; Altan, L.; Korkmaz, N. Effects of Pilates Exercises on Pain, Functional Status and Quality of Life in Women with Postmenopausal Osteoporosis. Journal of Bodywork and Movement Therapies 2013, 17, 204–211, doi:10.1016/j.jbmt.2012.07.003.
38. Oh, S.; Lim, J.-M.; Kim, Y.; Kim, M.; Song, W.; Yoon, B. Comparison of the Effects of Water- and Land-Based Exercises on the Physical Function and Quality of Life in Community-Dwelling Elderly People with History of Falling: A Single-Blind, Randomized Controlled Trial. Archives of Gerontology and Geriatrics 2015, 60, 288–293, doi:10.1016/j.archger.2014.11.001.
39. Schröder, G.; Knauerhase, A.; Kundt, G.; Schober, H.-C. Effects of Physical Therapy on Quality of Life in Osteoporosis Pa-tients - a Randomized Clinical Trial. Health Qual Life Outcomes 2012, 10, 101, doi:10.1186/1477-7525-10-101.
40. Angın, E.; Erden, Z.; Can, F. The Effects of Clinical Pilates Exercises on Bone Mineral Density, Physical Performance and Quality of Life of Women with Postmenopausal Osteoporosis. BMR 2015, 28, 849–858, doi:10.3233/BMR-150604.
41. Basat, H.; Esmaeilzadeh, S.; Eskiyurt, N. The Effects of Strengthening and High-Impact Exercises on Bone Metabolism and Quality of Life in Postmenopausal Women: A Randomized Controlled Trial. BMR 2013, 26, 427–435, doi:10.3233/BMR-130402.
42. Evstigneeva, L.; Lesnyak, O.; Bultink, I.E.M.; Lems, W.F.; Kozhemyakina, E.; Negodaeva, E.; Guselnikova, G.; Belkin, A. Effect of Twelve-Month Physical Exercise Program on Patients with Osteoporotic Vertebral Fractures: A Randomized, Controlled Trial. Osteoporos Int 2016, 27, 2515–2524, doi:10.1007/s00198-016-3560-4.
43. Peng, X.; Zhou, T.; Wu, H.; Li, Y.; Liu, J.; Huang, H.; He, C.; Guo, S.; Huan, M.; Shi, L.; et al. Effects of Weight-Bearing Dance Aerobics on Lower Limb Muscle Morphology, Strength and Functional Fitness in Older Women. PeerJ 2024, 12, e17606, doi:10.7717/peerj.17606.
44. Marchese, D.; D'Andrea, M.; Ventura, V.; Montalcini, T.; Foti, D.; Pujia, A.; Gulletta, E.; Iocco, M. Effects of a Weight-Bearing Exercise Training on Bone Mineral Density and Neuromuscular Function of Osteopenic Women. Eur J Inflamm 2012, 10, 427–435, doi:10.1177/1721727X1201000318.
45. Tolomio, S.; Ermolao, A.; Lalli, A.; Zaccaria, M. The Effect of a Multicomponent Dual-Modality Exercise Program Targeting Osteoporosis on Bone Health Status and Physical Function Capacity of Postmenopausal Women. J. of Women & Aging 2010, 22, 241–254, doi:10.1080/08952841.2010.518866.
46. Kanemaru, A.; Arahata, K.; Ohta, T.; Katoh, T.; Tobimatsu, H.; Horiuchi, T. The Efficacy of Home-Based Muscle Training for the Elderly Osteoporotic Women: The Effects of Daily Muscle Training on Quality of Life (QoL). Archives of Gerontology and Geriatrics 2010, 51, 169–172, doi:10.1016/j.archger.2009.10.003.
47. Wen, H.J.; Huang, T.H.; Li, T.L.; Chong, P.N.; Ang, B.S. Effects of Short-Term Step Aerobics Exercise on Bone Metabolism and Functional Fitness in Postmenopausal Women with Low Bone Mass. Osteoporos Int 2017, 28, 539–547, doi:10.1007/s00198-016-3759-4.
48. Park, H.J.; Han, B.; Chang, S.; Kang, S.H.; Lee, D.W.; Kang, S. Hand Grip Strength, Osteoporosis, and Quality of Life in Middle-Aged and Older Adults. Medicina 2023, 59, 2148, doi:10.3390/medicina59122148.
49. Di Blasio, A.; Sablone, A.; Leve, R.; Di Santo, S.; Bucci, I.; Giuliani, C.; Di Iorio, A.; Ripari, P.; Cugusi, L.; De Remigis, A.; et al. Circuit Training for Bone Health: Efficacy of the Bone-Based Rotation Exercises Principle: A Pilot Study. Sport Sci Health 2017, 13, 69–77, doi:10.1007/s11332-016-0312-y.
50. Górczewska, B.; Jakubowska-Pietkiewicz, E. Does the Duration of Postmenopausal Osteoporosis Affect Life Quality and Satisfaction? Arch Med Sci 2022, doi:10.5114/aoms/152780.
51. Mornar, M.; Novak, A.; Bozic, J.; Vrdoljak, J.; Kumric, M.; Vilovic, T.; Rakovic, I.; Ticinovic Kurir, T.; Martinovic, D.; Urlic, H.; et al. Quality of Life in Postmenopausal Women with Osteoporosis and Osteopenia: Associations with Bone Microar-chitecture and Nutritional Status. Qual Life Res 2024, 33, 561–572, doi:10.1007/s11136-023-03542-7.