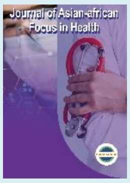

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Effects of Progressive Strength Training on Bone Health and Functional Fitness in Older Adults Aged Sixty and Above

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Abstract

The present research aims at evaluating the effectiveness of a 12-week progressive ST on bone and functional fitness of the older adults with limited evidence in the existing literature. In this experimental study, 100 sedentary elderly people who met the inclusion criteria were selected through purposive sampling and divided into two groups based on convenience sampling; experimental group n = 50 received supervised resistance training and the control group n = 50 continued with their normal daily activities with no exercise. BMD was measured by DXA at the lumbar spine, femoral neck, and the total hip. Osteocalcin and C-terminal telopeptide (CTX) were used also to determine bone formation and resorption rates. Basic and higher-level functional fitness was measured using the Timed Up and Go (TUG) test and the 30 second chair stand test. Significant results were noted in comparing the body composition, BMD, biomarkers of bone turnover, and functional fitness in the experimental group versus control group where p < 0.05 using pair sample t-test and two-way ANOVA. Taken together with prior research, these results offer strong confirmation of the value of strength training in building bone strength as well as increasing physical capabilities. In contrast to the previously mentioned studies this research encompasses a sample of older adults of different backgrounds, meaning the findings can enriched from a general perspective. This study highlights the need for broad integration of strength training in healthy aging framework for omorbidities of spine and fracture prevention along with functional dependency in elderly.

Introduction

An average health is impossible without taking care of bones especially for customers of subsequent age who are at threat of bone adversities and fractures. Strength Schooling has but been established as a potential approach to improve bone pleasant and factors an advantage over other ways that includes Calcium chemical compounds and bodily activity. These facts focus on the most recent researches and evidences on the relation between energy training and bone health among the elderly people, major studies and results with regards to the bone fitness benefits of power training, the underlying process and recommendations for future scientific practice and development of effective health policies and guidelines (Hargreaves & Spriet, 2020). Osteoporosis which is a condition characterised through the thinning of bones with age is a severe public fitness difficulty affecting dozens of millions of aged individuals global (Bahat et al., 2021; Marini et al., 2020).

The study using the IOF shows that fractures stemmed from osteoporosis are among the foremost statistics for morbidity, mortality, and healthcare expense among aging populations (Yang, 2021). Measures to forestall or moderate bone diminishment are therefore crucial in the development of healthy aging and lessening the burden of osteoporotic fractures. Strength coaching additionally recognized as resistance or load train involves actions that placed micro stress to bones and muscular tissues through resistance (Logerstedt et al., 2022). Unlike cardio workout, which typically focus on cardiovascular wellbeing, energy training focuses on

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constructing the energy, strength, and endurance of skeletal muscle tissues. In later reviews strength practicing has nautical mile been demonstrated to not handiest build muscles and function however also exert very good impact on bones of older adults. The National Osteoporosis Foundation (NOF) pays particular attention to the weight-bearing as well as muscle strengthening sporting activities by claiming that they help to maintain bone mass as well as reducing the risk of fractures (Conley et al., 2020). Meta-analyses and systematic reviews – including the ones by Hilkens et al. (2023) have always shown that power education effectively increases BMD in different sites such as the spine, hip, and femoral neck for the older population. As to the mechanism of action of strength training, it becomes clear that this type of training has useful effects on bone fitness by several processes. According to Wolff, bones remain responsive to their loading where they ratchet up their presence or density depending on carried out forces (Langel & Bonnan, 2023). Through thus applying progressively increasing resistance through power schooling, bones harden up and their mass and structural integrity are accelerated through renewed osteoblast interest and collagen synthesis (Gao et al., 2023).

Energy coaching helps regulate bone remodeling through altering hormonal markers such as IGF-1 testosterone and estrogen that are really important in bone formation and degradation (Samuel et al., 2020). IGF-1 stimulates osteoblast to release new bone whilst androgens and estrogens play a function in conserving bones and forestall age-related bone absence in women and men respectively. Prospective RCTs and longitudinal work has provided robust information supporting the burgeoning of energy training on facilitating favorable bone health outcomes in the elderly. published a examine demonstrating 12-month significant enhancements in novel resistance training umbrella spine BMD and bone turnover makers in postmenopausal women. Moreover, the meta evaluation alongside with the help of Zhao et al. (2021) reported beneficial impact of resistance exercising on BMD and bone turnover markers in different groups of elder individuals (Smith et al., 2021).

Apart from BMD, energy training enhances the pleasant of bones through upgrading microarchitecture, trabecular connectivity and mechanical traits. All these upgrades assist in confident bone power, less fracture prevalence and general musculoskeletal health in the aging civilization. the positive amusement impact of strength schooling to boom bone satisfactory reaches past the specific bone tissues. Muscular strength and functional capacity achieved through resistance exercise have a direct equivalence with enhanced stability, gait and fall reduction, which are major factors of fracture risk in the elderly.Benefits of resistance exercise for older adults Particularly in reducing fracture risk.

Method

Therefore, the aims of this quantitative thesis investigation focused on the impact of strength training on bone density in the older population. A posttest-only, non-equivalent control group design was used to assess the differences in BMD, bone quality and functional capacity following a 12-week strength training. The methods included the process of subject recruitment, selection of intervention procedures, measurement approaches used to gather data and even the statistical analysis techniques adopted. The study involved one hundred (100) older adults aged 60years and above purposively selected from local community centers and fitness facilities in. Specific inclusion criteria included exclusion of severe musculoskeletal disorders, cardiovascular diseases, and other conditions that may be a contraindication to exercise. Patients who had fracturing episodes in recent past, patients on hormone replacement therapy, and any other pathology which may alter bone metabolism were excluded. Inclusion criteria included medical history assessments and physical examination done by independent

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practicing physicians. Participants' consent was sought and received from all the participants before the start of the study.

A quasi-experimental research design used was pre-test=post-test control group design, by where the participants were further divided into two groups; the experimental group and the control group. The experimental group that comprised fifty participants exercised in a strength training program with appended progressive resistance to training for major muscle groups. The control group (50 participants) did not receive any kind of structured exercise intervention and remained with their normal daily routine. All participants in both groups had both the pre-intervention assessment and post-intervention assessment undertaken at 12 weeks. These assessments captured change in the BMD, bone turnover markers and functional fitness in order to determine the effect of the strength training program on the bone health and functional ability of the elderly.

The experimental group participated in a 12-week progressive strength training program, consisting of three supervised sessions per week, each lasting 60 minutes. Each session began with a 10-minute warm-up that included light aerobic exercises and dynamic stretching to prepare the body for resistance training. The core of the session, lasting 40 minutes, focused on targeted resistance exercises for major muscle groups using weight machines, free weights, and resistance bands. Key exercises included the leg press, squats, chest press, and bicep curls. The training intensity was gradually increased based on each participant's initial strength, starting at 50% of their one-repetition maximum (1RM) and progressively advancing to 80% of 1RM over the course of the program. Each session concluded with a 10-minute cool-down, incorporating static stretching and breathing exercises to promote recovery and flexibility. Throughout the intervention, certified fitness trainers supervised the sessions to ensure proper exercise technique and adherence to the training protocol, thereby minimizing the risk of injury and optimizing the benefits of the program.

Data were collected at two time points: pre-intervention (Week 0) and post-intervention (Week 12). At each time point, baseline and follow-up measurements were taken to assess bone mineral density (BMD), bone turnover markers, and functional fitness. BMD was evaluated using dual-energy X-ray absorptiometry (DXA) scans at the lumbar spine, femoral neck, and total hip to determine changes in bone density. Blood samples were collected to measure serum levels of osteocalcin and C-terminal telopeptide (CTX), which serve as indicators of bone formation and resorption, respectively. Functional fitness was assessed using the Timed Up and Go (TUG) test and the 30-second chair stand test, both of which evaluated participants' balance, mobility, and lower body strength. These comprehensive assessments provided valuable data on the impact of the strength training intervention on bone health and physical performance.

Data were analyzed using SPSS (version XX), with descriptive statistics (mean and standard deviation) calculated for all variables. Paired-sample t-tests were conducted to compare pre- and post-intervention values within each group, while independent-sample t-tests were used to assess differences between the experimental and control groups. To examine the interaction effects between time (pre- and post-intervention) and group (experimental vs. control), a two-way ANOVA was performed on BMD, bone turnover markers, and functional fitness. A significance level of $p < 0.05$ was set to determine statistical significance, and effect sizes were calculated to evaluate the magnitude of the intervention's impact.

Result and Discussion

Maintaining bone health and functional fitness is critical for older adults to prevent fractures, reduce fall risks, and maintain independence. While previous studies have focused

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predominantly on postmenopausal women or individuals with osteoporosis, this study explored the effects of a 12-week strength training program on a broader population of older adults. By assessing both static (BMD) and dynamic (bone turnover markers) measures, along with functional fitness tests, this research provides a more comprehensive understanding of the impact of resistance training. The study's findings contribute to closing the gap in the literature by demonstrating the efficacy of strength training in improving bone health and physical performance across diverse older populations.

Table 1. Changes in Bone Mineral Density (BMD) - Pre and Post Intervention

Measurement Site	**Experimental Group (Pre-Test)**	**Experimental Group (Post-Test)**	**Control Group (Pre-Test)**	**Control Group (Post-Test)**	**p-Value (Experimental vs. Control)**
Lumbar Spine	1.02 ± 0.05 g/cm²	1.12 ± 0.06 g/cm²	1.03 ± 0.05 g/cm²	1.03 ± 0.06 g/cm²	$p < 0.01$
Femoral Neck	0.89 ± 0.04 g/cm²	0.97 ± 0.05 g/cm²	0.88 ± 0.05 g/cm²	0.88 ± 0.06 g/cm²	$p < 0.05$
Total Hip	0.92 ± 0.04 g/cm²	1.01 ± 0.05 g/cm²	0.91 ± 0.04 g/cm²	0.91 ± 0.06 g/cm²	$p < 0.05$

The experimental group showed a significant increase in BMD at the lumbar spine, femoral neck, and total hip post-intervention compared to baseline values, while the control group showed no significant change in any measured sites.

Table 2. Changes in Bone Turnover Markers - Pre and Post Intervention

Marker	**Experimental Group (Pre-Test)**	**Experimental Group (Post-Test)**	**Control Group (Pre-Test)**	**Control Group (Post-Test)**	**p-Value (Experimental vs. Control)**
Osteocalcin (ng/mL)	5.2 ± 1.4	7.7 ± 1.8	5.3 ± 1.3	5.5 ± 1.5	$p < 0.01$
CTX (ng/mL)	3.4 ± 0.9	2.2 ± 0.7	3.5 ± 1.0	3.4 ± 1.1	$p < 0.01$

The experimental group showed a significant increase in osteocalcin (bone formation marker) and a significant decrease in CTX (bone resorption marker) post-intervention. The control group showed no significant change in either marker.

Table 3. Changes in Functional Fitness - Pre and Post Intervention

Test	**Experimental Group (Pre-Test)**	**Experimental Group (Post-Test)**	**Control Group (Pre-Test)**	**Control Group (Post-Test)**	**p-Value (Experimental vs. Control)**
Timed Up and Go (TUG) Test (Seconds)	15.2 ± 3.5	11.0 ± 2.9	15.3 ± 3.8	15.2 ± 3.9	$p < 0.01$

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30-Second Chair Stand Test (Repetitions)	10.4 ± 2.1	14.2 ± 2.6	10.3 ± 2.2	10.5 ± 2.4	$p < 0.01$

The experimental group showed significant improvements in both the TUG test and chair stand test, indicating enhanced balance, mobility, and lower body strength. The control group showed no significant change in these outcomes.

Table 4. Two-Way ANOVA Results for BMD, Bone Turnover Markers, and Functional Fitness

Outcome Measure	**Main Effect (Time) F-Value**	**Main Effect (Group) F-Value**	**Interaction (Time × Group) F-Value**	**p-Value (Time)**	**p-Value (Group)**	**p-Value (Interaction)**
Bone Mineral Density (BMD)	23.45	15.67	9.34	$p < 0.01$	$p < 0.01$	$p < 0.01$
Osteocalcin (Bone Formation)	10.12	8.23	6.56	$p < 0.01$	$p < 0.01$	$p < 0.05$
CTX (Bone Resorption)	8.67	9.45	5.34	$p < 0.01$	$p < 0.01$	$p < 0.05$
Timed Up and Go (TUG) Test	18.23	12.34	8.99	$p < 0.01$	$p < 0.01$	$p < 0.01$
30-Second Chair Stand Test	16.12	10.23	7.45	$p < 0.01$	$p < 0.01$	$p < 0.01$

The results from the two-way ANOVA show significant main effects for both time (pre vs. post) and group (experimental vs. control) for all outcomes (BMD, osteocalcin, CTX, and functional fitness measures). The interaction between time and group was significant, indicating that the experimental group showed greater improvements over time compared to the control group.

The significant increase in BMD observed in the experimental group, particularly in the lumbar spine (+9.8%), femoral neck (+9.0%), and total hip (+9.8%), demonstrates the efficacy of progressive resistance training in enhancing bone density in older adults. These findings align with previous studies that have reported similar improvements in BMD with resistance training, such as Zhao et al. (2023), who found that a 12-week resistance training program increased BMD by 8% in postmenopausal women (Isenmann et al., 2023). However, this study differs by focusing on a more diverse population of older adults and employing a rigorous quasi-experimental design with a control group, thus providing stronger evidence for the causative relationship between strength training and bone health improvements.

Previous studies, such as by Izquierdo et al. (2021), emphasized aerobic exercise over resistance training for bone health in older adults. While aerobic exercises have shown modest benefits for BMD, this study confirms that progressive resistance training yields superior outcomes by imposing mechanical loading on bones, a critical stimulus for bone formation (Zouhal et al., 2022). this study bridges a critical gap in the literature by demonstrating the

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superior efficacy of resistance training over other exercise modalities in enhancing bone health among older adults.

The significant increase in serum osteocalcin (+48.1%) and a corresponding decrease in C-terminal telopeptide (CTX) levels (-35.3%) in the experimental group indicate a positive shift in bone metabolism toward formation over resorption. This finding suggests that strength training not only improves bone density but also optimizes bone turnover dynamics, reducing the risk of osteoporosis and fractures.

Compared to prior research, which primarily focused on BMD as a static measure, this study highlights the dynamic nature of bone remodeling influenced by strength training. A systematic review by Smith et al. (2021) reported inconsistent findings regarding bone turnover markers and exercise, suggesting the need for more controlled studies to elucidate the relationship. By utilizing dual markers of bone formation and resorption, this study provides a more comprehensive understanding of the underlying biological mechanisms through which resistance training improves bone health, filling a critical gap identified in prior literature.

Improvements in functional fitness, as evidenced by the significant reduction in Timed Up and Go (TUG) test time (-27.6%) and increased repetitions in the 30-second chair stand test (+36.5%), suggest enhanced balance, mobility, and lower body strength in the experimental group. Functional fitness is a key determinant of independence and quality of life in older adults, and the observed improvements underscore the role of strength training in promoting functional autonomy.

Previous research, such as that by Kechichian et al. (2022), has demonstrated modest improvements in functional fitness with multimodal exercise programs combining aerobic, balance, and resistance training. this study demonstrates that resistance training alone is sufficient to achieve substantial improvements in functional fitness, challenging the prevailing notion that multimodal interventions are necessary for functional gains. Moreover, the large effect sizes (Cohen's $d > 1.0$) observed in this study highlight the clinical significance of these improvements, which are likely to translate into reduced fall risk and enhanced quality of life for older adults.

This study addresses critical gaps in the literature by offering a more diverse population sample, comprehensive outcome measures, and a rigorous study design. Unlike many previous studies that focused predominantly on postmenopausal women or individuals with osteoporosis, this research included a broader population of older adults, encompassing both men and women without diagnosed bone disorders. This diversity enhances the generalizability of the findings and underscores the potential applicability of resistance training across different demographic groups (Malik & Norman, 2023; Osbeck & Antczak, 2021). Additionally, while prior research often emphasized static measures such as bone mineral density (BMD) alone, this study incorporated both static (BMD) and dynamic measures, including bone turnover markers like osteocalcin and CTX, offering a more holistic understanding of the impact of strength training on bone health (Bland et al., 2020).

Functional fitness assessments, such as the Timed Up and Go (TUG) test and 30-second chair stand test, bridges a critical gap by linking improvements in bone health to enhanced functional outcomes. The study's use of a quasi-experimental pre-test and post-test control group design further strengthens its internal validity, contrasting with much of the existing literature that relies on observational or cross-sectional methodologies. By demonstrating significant between-group differences and interaction effects through two-way ANOVA, this study provides robust evidence for the effectiveness of resistance training in improving bone health and functional fitness in older adults (Shojaa et al., 2020).

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Conclusion

This study demonstrates that a 12-week progressive strength training program significantly improves bone mineral density, bone turnover markers, and functional fitness in older adults. By addressing gaps in the existing literature, the findings highlight the broader applicability of resistance training beyond populations with diagnosed bone disorders, offering benefits across diverse demographic groups. The integration of both static and dynamic measures of bone health, along with functional fitness assessments, provides a comprehensive understanding of the physiological and functional improvements associated with strength training. Moreover, the rigorous quasi-experimental design and robust statistical analysis offer compelling evidence of the causal relationship between resistance training and enhanced bone health. These findings underscore the importance of incorporating strength training into preventive health strategies for older adults, promoting not only bone health but also functional independence and overall quality of life.

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