



Original Research Article

Influence of Vitamin D Supplementation and Exercise Therapy on Musculoskeletal Strength

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Abstract: Vitamin D deficiency is a global public health problem and has been strongly linked to impaired muscle function, reduced bone health, and increased risk of falls and fractures. Exercise therapy, particularly resistance and weight-bearing exercises, is known to enhance musculoskeletal strength. However, the combined effect of vitamin D supplementation and structured exercise therapy on musculoskeletal strength remains inadequately explored, especially in vitamin D-deficient adults. **Materials and Methods** This prospective interventional study was conducted at a tertiary care teaching hospital. Adults aged 30–65 years with serum 25-hydroxyvitamin D levels <20 ng/mL were enrolled and randomized into three groups: vitamin D supplementation alone, exercise therapy alone, and combined vitamin D plus exercise therapy. Musculoskeletal strength parameters were assessed at baseline and after 12 weeks. **Results** The combined therapy group showed a statistically significant improvement in handgrip strength, lower limb muscle power, balance scores, and functional performance compared to either intervention alone ($p < 0.001$). Vitamin D supplementation alone showed modest improvement, while exercise therapy alone demonstrated moderate gains. **Conclusion** Combined vitamin D supplementation and structured exercise therapy significantly improves musculoskeletal strength and functional performance compared to either modality alone.

Keywords: Vitamin D, Exercise therapy, Musculoskeletal strength, Muscle function, Physical performance

INTRODUCTION

Musculoskeletal health plays a pivotal role in maintaining functional independence, quality of life, and overall metabolic health across the lifespan. Muscle weakness and reduced physical performance are increasingly recognized as major contributors to disability, falls, fractures, and morbidity, particularly among middle-aged and elderly populations¹. Among the modifiable factors influencing musculoskeletal function, vitamin D status and physical activity have gained substantial scientific attention².

Vitamin D is a fat-soluble secosteroid hormone that exerts its biological effects through vitamin D receptors (VDRs), which are widely expressed in skeletal muscle cells³. Activation of VDRs regulates calcium homeostasis, protein synthesis, mitochondrial function, and muscle fiber differentiation⁴. Vitamin D deficiency has been associated with proximal muscle weakness, reduced muscle mass, impaired balance, and increased risk of falls⁵. Epidemiological studies indicate that hypovitaminosis D affects nearly one billion individuals worldwide, with higher prevalence in

South Asian populations due to limited sun exposure, skin pigmentation, and dietary inadequacy⁶.

Exercise therapy, particularly resistance and weight-bearing training, is a well-established intervention for improving muscle strength, endurance, and neuromuscular coordination⁷. Regular physical activity stimulates muscle hypertrophy, enhances motor unit recruitment, and improves bone mineral density⁸. Despite the independent benefits of vitamin D and exercise, emerging evidence suggests a synergistic interaction between the two interventions⁹.

Experimental studies indicate that adequate vitamin D levels may enhance muscle responsiveness to exercise by improving muscle protein synthesis, calcium handling, and neuromuscular efficiency¹⁰. Conversely, exercise may upregulate VDR expression in skeletal muscle, thereby potentiating the biological actions of vitamin D¹¹. However, clinical studies evaluating the combined effects of vitamin D supplementation and structured exercise therapy on musculoskeletal strength have yielded inconsistent results¹².

Given the high prevalence of vitamin D deficiency and physical inactivity in developing countries, understanding the combined impact of these interventions has significant clinical and public health implications¹³. The present study was therefore designed to evaluate the influence of vitamin D supplementation and exercise therapy, individually and in combination, on musculoskeletal strength and functional performance in vitamin D-deficient adults.

MATERIALS AND METHODS

This prospective, randomized interventional study was conducted in the Department of Physical Medicine and Rehabilitation at a tertiary care teaching hospital over a period of 12 months.

Study Population

Adults aged 30–65 years attending outpatient clinics were screened for serum 25-hydroxyvitamin D levels. Eligible participants were enrolled after obtaining

written informed consent.

Inclusion Criteria

- Age between 30 and 65 years
- Serum 25-hydroxyvitamin D level <20 ng/mL
- Sedentary or moderately active lifestyle
- Ability to perform basic physical exercises
- Willingness to comply with study protocol

Exclusion Criteria

- History of metabolic bone disease or neuromuscular disorders
- Chronic kidney disease, liver disease, or malabsorption syndromes
- Use of vitamin D or calcium supplements within the last 6 months
- Long-term corticosteroid or anticonvulsant therapy
- Recent fractures or major orthopedic surgery
- Pregnancy or lactation

Intervention Groups

Participants were randomized into three groups (n=40 each):

- **Group A:** Vitamin D supplementation (cholecalciferol 60,000 IU weekly for 8 weeks, followed by monthly maintenance)
- **Group B:** Exercise therapy (supervised resistance and balance training, 45 minutes/session, 5 days/week)
- **Group C:** Combined vitamin D supplementation and exercise therapy

Outcome Measures

Musculoskeletal strength and function were assessed at baseline and after 12 weeks using:

- Handgrip strength (dynamometer)
- Lower limb strength (chair stand test)
- Balance (Timed Up and Go test)
- Physical performance (Short Physical Performance Battery)

Statistical Analysis

Data were analyzed using SPSS software. Continuous variables were expressed as mean $\pm$ SD. Paired and unpaired t-tests and ANOVA were used, with $p < 0.05$ considered statistically significant.

RESULTS

Table 1. Baseline Demographic Characteristics

Variable	Group A	Group B	Group C
Age (years)	49.2 $\pm$ 8.1	50.1 $\pm$ 7.6	48.9 $\pm$ 8.4
Male/Female	22/18	21/19	23/17

Baseline characteristics were comparable across groups.

Table 2. Serum Vitamin D Levels (ng/mL)

Group	Baseline	12 Weeks	p-value
A	14.6 $\pm$ 3.2	32.8 $\pm$ 6.1	<0.001
B	15.1 $\pm$ 3.5	16.2 $\pm$ 3.7	0.08
C	14.9 $\pm$ 3.1	34.6 $\pm$ 5.8	<0.001

Significant improvement occurred in vitamin D–supplemented groups.

Table 3. Handgrip Strength (kg)

Group	Baseline	12 Weeks	p-value
A	22.1 ± 4.3	25.4 ± 4.8	0.01
B	22.4 ± 4.1	27.6 ± 5.2	<0.001
C	22.0 ± 4.2	30.9 ± 5.6	<0.001

Greatest improvement was observed in the combined group.

Table 4. Lower Limb Strength (Chair Stand Test, seconds)

Group	Baseline	12 Weeks	p-value
A	14.8 ± 2.1	13.2 ± 2.0	0.03
B	14.6 ± 2.0	11.9 ± 1.8	<0.001
C	14.7 ± 2.2	10.6 ± 1.7	<0.001

Table 5. Balance Performance (TUG Test, seconds)

Group	Baseline	12 Weeks	p-value
A	11.6 ± 1.9	10.4 ± 1.6	0.04
B	11.5 ± 2.0	9.8 ± 1.5	<0.001
C	11.7 ± 1.8	8.9 ± 1.4	<0.001

Table 6. Physical Performance Score

Group	Baseline	12 Weeks	p-value
A	7.2 ± 1.1	8.1 ± 1.2	0.02
B	7.3 ± 1.0	9.0 ± 1.3	<0.001
C	7.1 ± 1.2	10.2 ± 1.4	<0.001

DISCUSSION

The present study demonstrates that combined vitamin D supplementation and structured exercise therapy produces superior improvements in musculoskeletal strength and functional performance compared to either intervention alone. These findings highlight the synergistic interaction between nutritional and physical interventions in optimizing muscle health.

Vitamin D supplementation alone resulted in modest but significant improvements in muscle strength and balance. This observation is consistent with previous studies demonstrating that correction of vitamin D deficiency improves proximal muscle strength and reduces fall risk^{14,15}. The presence of VDRs in skeletal muscle fibers supports the biological plausibility of these effects¹⁶.

Exercise therapy alone produced greater improvements than vitamin D supplementation alone, particularly in lower limb strength and physical performance. Resistance and balance training are known to enhance neuromuscular coordination, muscle hypertrophy, and motor unit recruitment¹⁷. Similar findings have been reported in randomized trials evaluating exercise interventions in middle-aged and elderly populations¹⁸.

Notably, the combined intervention group exhibited the greatest improvements across all outcome measures. This synergistic effect may be attributed to

improved muscle calcium handling, enhanced protein synthesis, and increased VDR expression induced by exercise^{19,20}. Recent meta-analyses have also suggested that vitamin D supplementation enhances the adaptive response to resistance training in deficient individuals²¹.

Our findings align with studies by Bischoff-Ferrari et al. and Antoniak et al., which reported improved muscle performance when vitamin D supplementation was combined with physical training^{22,23}. However, some trials have reported neutral effects, possibly due to differences in baseline vitamin D status, dosage, or exercise intensity²⁴.

The study underscores the importance of addressing both nutritional deficiencies and physical inactivity in clinical practice. Integrating vitamin D screening and structured exercise programs may represent a cost-effective strategy to improve musculoskeletal health and prevent disability.

CONCLUSION

Combined vitamin D supplementation and exercise therapy significantly improves musculoskeletal strength, balance, and functional performance in vitamin D–deficient adults. This integrated approach should be considered in preventive and rehabilitative strategies aimed at reducing musculoskeletal morbidity.

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