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Vitamin D supplementation enhances neuromuscular function in older adults: controlled clinical trial

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Abstract

Vitamin D deficiency has been associated with impaired neuromuscular performance and increased risk of falls in older adults. Supplementation may improve physical function, but evidence remains inconsistent. This study aimed to determine the impact of vitamin D supplementation on neuromuscular performance among older adults with vitamin D insufficiency.

A single-blinded controlled clinical trial was conducted on 60 participants (aged 60-75 years) with serum vitamin D levels <30 nmol, recruited from the Geriatric Unit of the institution. Participants were randomized into intervention (vitamin D 60,000 IU weekly for 12 weeks, n=30) and placebo (identical capsules, n=30) groups. Baseline and post-intervention assessments included sociodemographic data, serum vitamin D, and neuromuscular function using the Short Physical Performance Battery (SPPB: balance, chair stand, gait speed). Data were analyzed using chi-square and paired t-tests, with $p<0.05$ considered significant.

Baseline characteristics were comparable between groups except for socioeconomic status. After 12 weeks, the intervention group showed significant improvements in serum vitamin D levels and neuromuscular performance compared with placebo. Gait speed improved with a relative reduction in time of 73% ($p=0.006$). Chair stand test performance improved by a mean difference of 2.67 seconds, reflecting a 90% relative change ($p<0.001$). Balance scores also improved significantly ($p<0.001$).

Vitamin D supplementation led to significant gains in neuromuscular performance in older adults with insufficiency. These findings suggest that regular supplementation may serve as a simple, low-cost intervention to improve functional outcomes and potentially reduce fall risk in older adults.

Key words: accidental falls, dietary supplements, physical functional performance, vitamin D, walking speed.

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Introduction

Vitamin D deficiency is a major global health concern, with prevalence rates among older adults reported as high as 50-90%.[1-3] This deficiency frequently coincides with age-related decline in neuromuscular function, including reduced muscle strength, impaired postural control, and greater susceptibility to falls.[4] This condition is known as sarcopenia, and its prevalence is 10-27% of the elderly globally,[5] while among the Indian older adults, it has a prevalence of 39.2%.[6] Such changes contribute significantly to morbidity and loss of independence in elderly populations, highlighting the importance of exploring vitamin D's role in neuromuscular health through interventional research.

The physiological mechanisms linking vitamin D to neuromuscular function are increasingly well described. Skeletal muscle expresses vitamin D receptors (VDRs), through which the active metabolite, 1,25-dihydroxyvitamin D, regulates gene transcription involved in muscle protein synthesis, calcium homeostasis, mitochondrial function, and muscle cell proliferation.[7,8] Adequate vitamin D levels support type II muscle fiber size and contractility, enhance balance and coordination, and optimize calcium flux at the neuromuscular junction, thereby improving nerve conduction and reaction time. Conversely, deficiency is associated with muscle weakness, impaired gait, and increased risk of falls.[9] Evidence from various clinical studies suggests that vitamin D supplementation can improve lower-limb strength, functional mobility, and fall outcomes, particularly in individuals with baseline deficiency.[10]

However, findings remain inconsistent due to variability in study design, supplementation dose, intervention duration, and outcome measures. Despite these insights, much of the available evidence originates from Western populations, with limited literature addressing older adults in developing countries such as India, where unrecognized vitamin D deficiency is common. This highlights the need for region-specific interventional studies to determine the impact of vitamin D supplementation on neuromuscular performance. Understanding the role of vitamin D may help develop strategies to reduce mobility-related disability in ageing populations, thereby preserving independence and enhancing quality of life in older adults.

Materials and Methods

Study design and participants

This single-blinded controlled clinical trial was conducted after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrolment. A total of 60 subjects, aged 60-75 years, were recruited from the Geriatric Unit of the Institution.

Eligibility criteria

Inclusion criteria were: healthy individuals of either gender, aged 60-75 years, with serum vitamin D levels <30 nmol, and who provided written informed consent. Exclusion criteria included: a history of neuropsychiatric disorders; chronic illnesses (*e.g.*, kidney or liver disease); use of medications affecting neuromuscular mobility, anticonvulsants, or glucocorticoids; malabsorption syndromes (*e.g.*, celiac disease, Crohn's disease, cystic fibrosis); physical disability; and non-cooperative behavior.

Blinding and randomization

The study comprised 60 participants and employed a single-blind design, in which all eligible participants were unaware of their group allocation. To maintain blinding, vitamin D and placebo (sugar) capsules were identical in appearance. Random allocation procedure was ensured, as only the researcher was aware of the group assignments. Eligible participants were assigned sequential identification numbers generated using an online randomization tool and were alternately allocated to either the intervention (n=30) or the placebo group (n=30).

Procedure

All participants underwent screening through detailed personal and medical history, general physical examination, and serum vitamin D measurement. Sociodemographic information, educational status, daily sun exposure, and dietary habits were recorded. Socioeconomic status was classified using the updated B.G. Prasad scale (April 2023).[11]

The skin type was assessed using the Fitzpatrick classification scale of skin types I through VI.[12] Baseline assessments included serum vitamin D levels and neuromuscular function, as measured by the Short Physical Performance Battery (SPPB).[13]

Intervention

Participants in the intervention group received oral vitamin D supplementation (60,000 IU) once weekly for 12 weeks, according to the guidelines of the Endocrine Society of India.[14] The placebo group received identical-appearing inert "sugar capsules" without active ingredients.

Outcome measures

The primary outcome was the change in serum vitamin D levels. The secondary outcome was the change in neuromuscular function, as assessed by the SPPB, after 12 weeks.

Short Physical Performance Battery

Lower extremity function was assessed using SPPB, which includes three domains: balance, gait speed, and chair stand performance. The total score ranges from 0 (worst performance) to 12 (best performance), with higher scores indicating better physical function (Figure 1).

Balance test – participants were instructed to maintain three progressively challenging positions: side-by-side (feet together), semi-tandem (one foot partially forward), and tandem (one foot directly in front of the other), each for a maximum of 10 seconds. Scoring was assigned as <3 seconds=0 points; 3-9.99 seconds=1 point; and 10 seconds=2 points.

Gait speed – usual walking speed was measured over a 4 m course. Scores were based on completion time: unable=0 points; >8.70 seconds=1 point; 6.21-8.70 seconds=2 points; 4.82-6.20 seconds=3 points; and <4.82 seconds=4 points.

Chair-stand test – muscle strength of the lower limbs was evaluated by timing participants as they rose from a chair and sat down five times consecutively without using their arms. Scoring was as follows: unable or >60 seconds=0 points; >16.70 seconds=1 point; 13.70-16.69 seconds=2 points; 11.20-13.69 seconds=3 points; and ≤11.19 seconds=4 points.

Relative change (within group) in mean change in percentage (%) was calculated as (12-week mean − baseline mean) / baseline mean × 100.

The relative difference (between groups) in mean change in percentage (%) was calculated using Eq. 1:

$$\text{Relative Difference (\%)} = \frac{\text{Mean change}_{\text{Vitamin D}} - \text{Mean change}_{\text{Placebo}}}{\text{Mean change}_{\text{Vitamin D}}} \times 100 \quad \text{[Eq. 1]}$$

Statistical analysis

Data were entered into Microsoft Excel and analyzed using standard statistical methods. Continuous variables were expressed as mean ± standard deviation, and categorical variables as percentages or proportions. The chi-square test was applied for categorical data. Within-group at baseline and follow-up, the p-values were calculated using paired t-tests. Between-group adjusted p-values were obtained using analysis of covariance (ANCOVA), with 12-week SPPB score as the dependent variable, study group as the fixed factor, and baseline SPPB score and socioeconomic category as covariates. A p-value <0.05 was considered statistically significant.

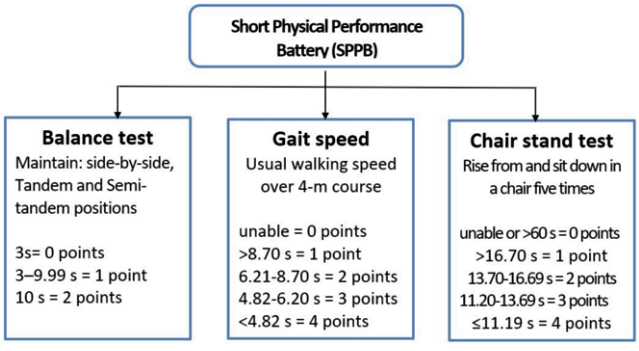

Figure 1. Flow diagram of the Short Physical Performance Battery (SPPB) domains and scoring criteria.

Results

The baseline characteristics of participants in the interventional and placebo groups were largely comparable. There were no significant differences between the groups with respect to gender, residence, education, employment status, or food habits ($p>0.05$). Family type and religion showed borderline differences ($p\approx0.05$-0.06). A statistically significant difference was observed in socioeconomic status ($p=0.005$), with a higher proportion of participants in the placebo group belonging to the upper-middle class. Overall, the groups were well matched except for socioeconomic status (Table 1).

The distribution of skin color, as classified by the Fitzpatrick scale, was comparable between the interventional and placebo groups. Most participants belonged to type III and IV categories. Statistical analysis using the chi-square test ($\chi^2=2.13$, df=2, $p=0.35$) revealed no significant difference between groups (Table 2).

At baseline, most blood parameters were comparable between groups. After 12 weeks, the intervention group showed a significant increase in vitamin D and a significant reduction in serum parathyroid hormone compared with the placebo group, while calcium and phosphorus showed no significant between-group differences (Figure 2).

After 12 weeks, the intervention group showed significantly greater improvements than the placebo group across all SPPB components after adjustment for baseline performance and socioeconomic status using ANCOVA. Improvements were reflected by increased time to stand in the tandem and semi-tandem test, while improved performance in the 4 m gait test and chair stand test was indicated by a reduction in completion time. The magnitude of intervention effects was large for the chair stand test ($\eta p^2=0.51$) and semi-tandem test ($\eta p^2=0.51$), and moderate to large for tandem gait ($\eta p^2=0.34$) and four-meter gait test ($\eta p^2=0.14$). Relative differences favored the intervention group, with improvements of 89.9% in chair stand performance, 67.6% in semi-tandem balance, 73.0% in gait speed, and 50.0% in tandem gait compared with placebo (Table 3).

Table 1. Baseline characteristics of participants in the interventional and placebo groups.

Sociodemographic variables	Interventional group (n=30), n (%)	Placebo group (n=30), n (%)	Test used	p
Gender	Female: 17 (57) Male: 13 (43)	Female: 16 (53) Male: 14 (47)	Fisher's exact	1.000
Residence	Rural: 7 (23) Urban: 23 (77)	Rural: 3 (10) Urban: 27 (90)	Fisher's exact	0.299
Family type	Joint: 14 (47) Nuclear: 9 (30) Three-generation: 7 (23)	Joint: 18 (60) Nuclear: 2 (7) Three-generation: 10 (33)	χ^2 test	0.064
Religion	Hindu: 25 (83) Muslim: 5 (17)	Hindu: 30 (100) Muslim: 0 (0)	Fisher's exact	0.052
Education	Graduate: 2 (7) Primary: 11 (37) Secondary: 17 (57)	Graduate: 4 (13) Primary: 14 (47) Secondary: 12 (40)	χ^2 test	0.389
Employment	Employed: 16 (53) Retired: 1 (3) Unemployed: 13 (43)	Employed: 11 (37) Retired: 0 (0) Unemployed: 19 (63)	χ^2 test	0.218
Socioeconomic status	Upper: 1 (3) Upper-middle: 16 (53) Middle: 13 (43)	Upper: 2 (7) Upper-middle: 26 (87) Middle: 2 (7)	χ^2 test	**0.005**
Food habits	Non-veg: 5 (17) Veg: 25 (83)	Non-veg: 1 (3) Veg: 29 (97)	Fisher's exact	0.195

For categorical variables, Chi-square tests (χ^2) were applied when all expected cell frequencies ≥5; Fisher's exact tests were used when expected frequencies were <5. Significant p-values ($p<0.05$) are in bold.

Table 2. Skin color distribution according to Fitzpatrick scale in interventional and placebo groups.

Fitzpatrick skin type	Interventional (n=30), n (%)	Placebo (n=30), n (%)
Type 1	0 (0)	0 (0)
Type 2	2 (6.7)	0 (0)
Type 3	13 (43.3)	13 (43.3)
Type 4	15 (50.0)	17 (56.7)
Type 5	0 (0)	0 (0)
Type 6	0 (0)	0 (0)
χ^2 (df=2)	2.13	p=0.35

Since rows 1, 5, and 6 are all zero counts, they do not contribute to the test.

The intervention (vitamin D) group demonstrated greater improvement than the placebo group across all SPPB components over 12 weeks. Notably, chair stand time and four-meter gait speed improved with reduced completion time. In contrast, tandem, and semi-tandem test time increased more markedly in the intervention group, indicating enhanced strength and balance (Figure 3).

Discussion

This controlled clinical trial demonstrates that vitamin D supplementation in older adults with vitamin D insufficiency leads to significant improvements in neuromuscular performance. After 12 weeks, gait speed, chair stand performance, and balance

Table 3. Comparison of Short Physical Performance Battery test results (sec.) between intervention and placebo groups.

SPPB test	Study group (n=30)	Baseline Mean±SD	12 weeks Mean±SD	Within-group p†	Mean change ± SD	Within group relative change (%)	Between-group relative difference (%)	Between-group adjusted p‡	Effect size (ηp^2)
4 m gait test	Intervention	4.93±0.83	4.30±0.47	<0.001	-0.63±0.61	-12.8	73.0	<0.001	0.135 (medium)
	Placebo	4.80±0.71	4.63±0.76	0.12	-0.17±0.65	-3.5			
Chair stand test	Intervention	18.30±6.76	15.63±6.27	<0.001	-2.67±0.99	-17.1	89.9	<0.001	0.510 (large)
	Placebo	11.93±3.34	11.67±3.49	0.18	-0.27±1.14	-2.3			
Tandem gait test	Intervention	10.00±0.87	11.80±0.76	<0.001	1.80±0.61	18.0	50.0	0.002	0.337 (large)
	Placebo	10.03±1.19	10.93±1.53	0.01	0.90±0.76	9.0			
Semi-tandem gait test	Intervention	8.70±1.24	11.17±0.87	<0.001	2.47±0.86	28.4	67.6	<0.001	0.509 (large)
	Placebo	9.70±0.99	10.50±0.68	0.01	0.80±0.55	8.2			

SD, standard deviation; SPPB, Short Physical Performance Battery. Values are expressed as mean±SD. †Within-group p-values calculated using paired t-tests. ‡Between-group adjusted p-values calculated using analysis of covariance adjusting for baseline SPPB component score and socioeconomic category. Effect size reported as partial eta squared (ηp^2): 0.01=small, 0.06=medium, ≥0.14=large.

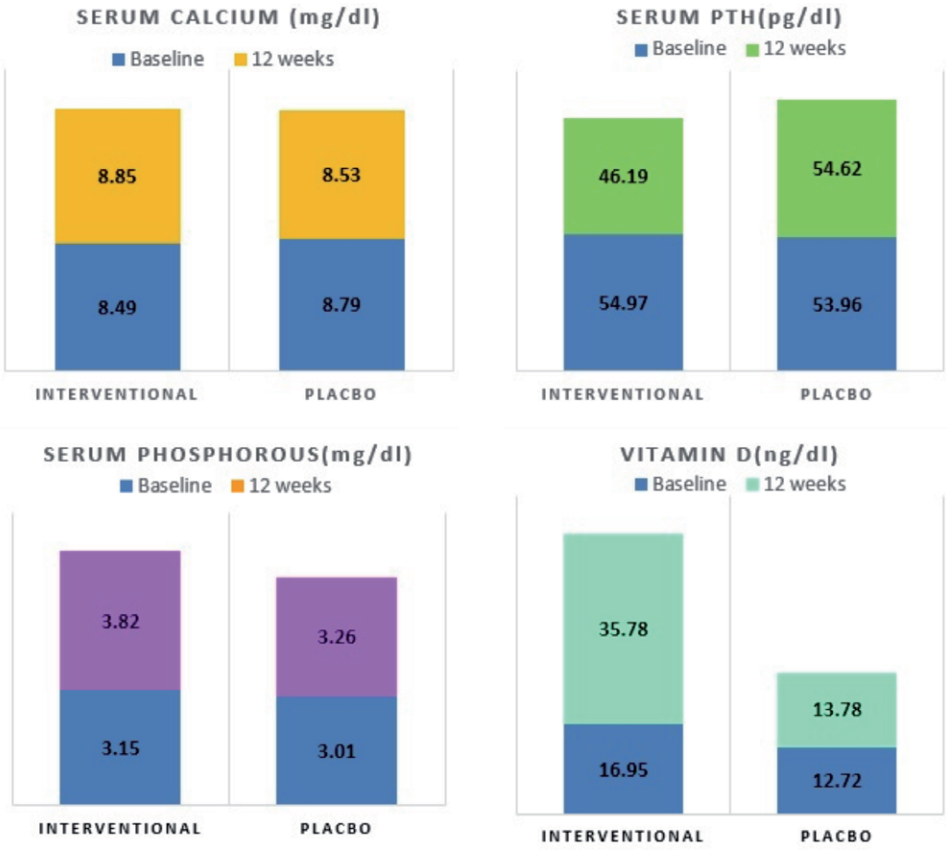

Figure 2. Comparison of serum biochemical parameters between intervention and placebo groups at baseline and after 12 weeks.

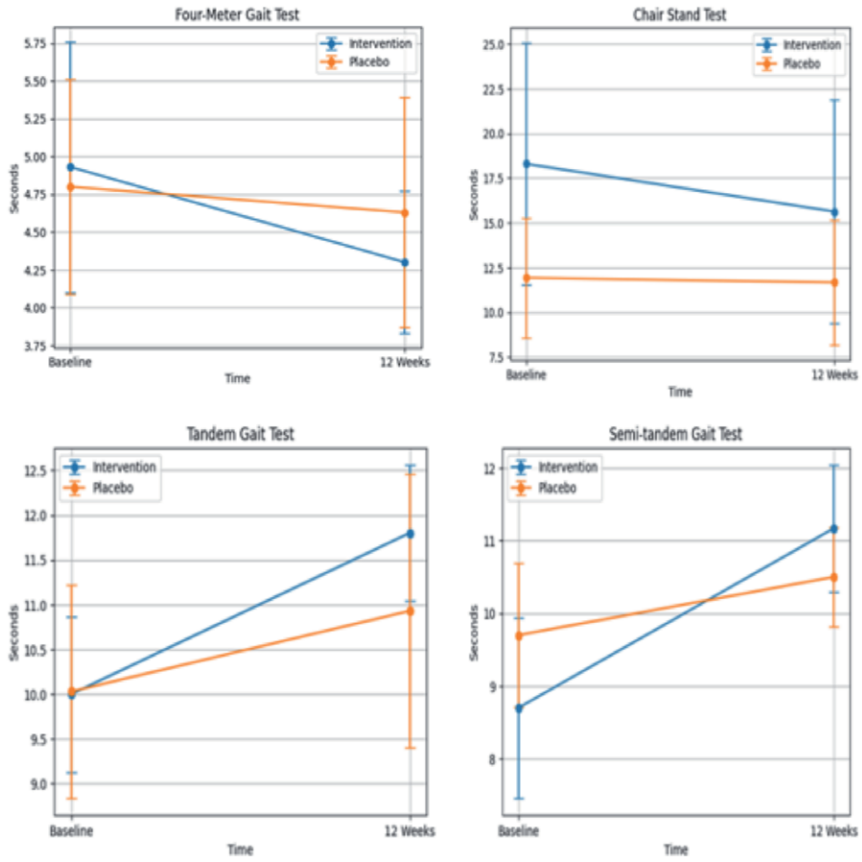

Figure 3. Effect of vitamin D supplementation on physical performance measures (Short Physical Performance Battery) over 12 weeks.

scores improved in the intervention group compared with placebo, accompanied by a marked rise in serum 25(OH)D levels. These results provide compelling evidence that correcting vitamin D deficiency contributes to better functional outcomes, supporting its role beyond skeletal health and underscoring its relevance for maintaining independence in ageing populations.

Our findings align with earlier research studies that report enhanced lower extremity function and reduced fall risk following vitamin D supplementation,[15] as well as improvements in muscle fiber composition and contractility linked to VDR activity.[5] Observational studies have further highlighted positive associations between higher 25(OH)D concentrations and physical performance metrics such as gait speed and chair rise ability.[16] However, evidence from interventional trials has been heterogeneous, with some demonstrating benefits,[17-19] while others reported minimal or no effects.[20,21] These inconsistencies likely reflect variability in baseline vitamin D status, age, mobility levels, and co-interventions such as calcium supplementation.

The clear improvements observed in the present study may be attributable to the correction of deficiency at baseline, emphasizing the importance of targeting populations most likely to benefit. Taken together, these findings strengthen the growing body of evidence that adequate vitamin D status is essential for neuromuscular health and may represent a modifiable factor to preserve physical function and quality of life in older adults.

Strengths and limitations

The study employed standardized and validated tools, such as the SPPB and Fitzpatrick skin classification, to ensure reliable assessment of neuromuscular function and skin type. Biochemical confirmation of vitamin D status added objectivity to outcome measures. However, the small sample size (n=60) and single-center setting may limit generalizability. Baseline differences in socioeconomic status between groups could not be fully eliminated despite randomization. The short intervention duration of 12 weeks, along with the absence of interim functional assessments, may limit evaluation of progressive or long-term effects. The present study was a single-blind controlled clinical trial, which may have introduced subtle bias affecting study outcomes due to the absence of allocation concealment, which could have influenced participant assignment.

Conclusions

This controlled clinical trial found that vitamin D supplementation significantly improved neuromuscular performance in older adults with vitamin D deficiency. Participants receiving supplementation showed marked gains in gait speed, chair stand performance, and balance compared with placebo, underscoring its role in enhancing functional mobility. Overall, vitamin D supplementa-

tion appears to be a simple, safe, and cost-effective strategy to improve physical performance and potentially reduce fall risk among older adults.

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Informed consent: participants gave written consent for anonymous clinical data collection.

Patient consent for publication: not applicable.

Availability of data and materials: data will be available upon reasonable request to the corresponding author.

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