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Original Article

The effect of vitamin D supplementation on cardiorespiratory fitness and muscle strength in male adults undergoing basic military training

A.S. Menon ^{a,*}, S. Anayath ^b, M.K. Garg ^c, Ravi Kapoor ^d, I. Pisharody ^e^a Commandant, Military Hospital, Mhow, India^b Col Trg, AMC Centre & College, Lucknow, India^c Professor & Head (Medicine) & Endocrinology, AIIMS, Jodhpur, India^d Graded Specialist (Biochemistry), Command Hospital (Central Command), Lucknow, India^e Associate Professor (Physiology), Career Institute of Medical Sciences, Lucknow, India

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ABSTRACT

Background: Vitamin D deficiency (VDD) is ubiquitous in the Indian subcontinent. VDD has been shown to impair muscle functions. However, the association of VDD with cardiorespiratory endurance is uncertain. Hence, we enrolled and supplemented vitamin D in military recruits with VDD with an aim to evaluate effect of supplementation on cardiorespiratory endurance and muscle strength.

Method: We enrolled 90 military recruits with VDD and randomly allotted them to two groups equally. The group I received cholecalciferol granules 60,000 IU every fortnight for twelve weeks (cases), and the group II was observed as control. Muscle strength and cardiorespiratory endurance was assessed with a battery of tests (standing broad jump, bent arm hang test, 20 m shuttle run) at baseline and repeated at the end of training (nineteen weeks). Blood samples were collected for measurement of serum 25(OH)D and parathyroid hormone.

Results: In Group I and Group II, there was significant increase in 25(OH) D levels (25.8 ± 7.1 and 17.3 ± 3.5 ng/ml, respectively), and in VO₂ max (9.8 ± 8.8 and 12.7 ± 8.6 ml/kg/min, respectively) compared with the baseline values. However, no significant change was observed in muscle strength after supplementation. There was no difference between the groups in VO₂ max and muscle strength at baseline and at the end of training.

Conclusion: Vitamin D supplementation did not improve muscle strength and cardiorespiratory endurance in military recruits with VDD. A significant rise in 25(OH) D was observed even in those not supplemented with vitamin D.

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* Corresponding author.

E-mail address: menonara@yahoo.com (A.S. Menon).<https://doi.org/10.1016/j.mjafi.2018.12.004>

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Introduction

There is widespread prevalence of vitamin D deficiency (VDD) in the Indian subcontinent with up to two-third of participants showing low levels of 25-hydroxy-vitamin D (25[OH]D) in studies conducted in diverse populations.^{1–4} The high prevalence of VDD despite adequate sunshine has been attributed to inadequate sun exposure, decreased vitamin D synthesis due to darker skin, vegetarian diet and lack of Vitamin D fortification programme⁵. The classic manifestation of VDD is due to alteration of calcium metabolism and manifests as rickets in childhood and osteomalacia in adults.⁶ Vitamin D has increasingly been studied for its role in a wide range of cardiovascular, autoimmune, malignant, infectious, metabolic and other diseases.⁷ Vitamin D receptors (VDRs) have been demonstrated on skeletal muscle⁸. VDD is associated with proximal muscle weakness and, in elderly, a propensity for falls.⁹ Trials have shown beneficial effects of supplementation of vitamin D on skeletal muscle function in elderly¹⁰; however, similar effect is uncertain in young population. Cardiorespiratory fitness reflects the ability of the body to work continuously for extended period of time. The association of vitamin D and cardiorespiratory fitness has been studied in western population, but the outcomes have been mixed. Studies in adolescents and young adults have shown positive^{11,12} or no association^{13,14} between vitamin D and cardiorespiratory fitness. Individuals enrolled for military service have to undergo a gruelling period of physical training, which is aimed at building their cardiorespiratory fitness and muscle strength. This study was planned to evaluate the effect of vitamin D supplementation on parameters of muscle strength and cardiorespiratory fitness in military recruits (healthy young male adults > 18 years) with VDD undergoing basic military training for 19 weeks.

Materials and Methods

The institutional ethical committee approved the study. We conducted this study from April 2017 to August 2017 on recruits screened for VDD at a regimental training centre located in North India at 26.8° N, 80.9° E.

Sample size

A sample size of 44 in each arm of the study was arrived at to study the effect of vitamin D supplementation on muscle strength. (assuming 80% power, 5% significance level with 95% confidence interval as well as assuming 10% margin of error). We included participants with vitamin D deficiency (serum 25(OH)D 20 ng/ml).⁶ We excluded individuals reporting with systemic illness, musculoskeletal symptoms and those who had taken nutritional supplement or vitamin D before enrolment.

Intervention

Among those with VDD, using block randomisation (blocks of 4 and 6 with allocation ratio of 1:1), participants were either assigned to be administered vitamin D supplementation

(cholecalciferol granules 60,000 U) orally every fortnight for twelve weeks (group I) or to be observed without any supplement and act as control (group II). Participants in both the groups underwent basic military training of nineteen weeks, which consisted of outdoor training coupled with classroom instructions. All participants were on a standard scale of ration provided during recruit training. None of the food provided was fortified with vitamin D. All the participants underwent training in the open ground with approximately 21% of skin exposed (face, hands, forearm and 50% of the arm) until 1200 h daily (except Sundays and holidays) for nineteen weeks during the study period. Primary outcome studied was, change in parameters of cardiorespiratory fitness and muscle strength.

Demographic information, dietary pattern, sunlight exposure and assessment of socio-economic status were recorded on a standard questionnaire before recruitment. Height and weight was measured for calculation of body mass index ($BMI = \text{weight}/\text{height}^2$) using a portable stadiometer and weighing scale. Lean mass was measured with dual-energy X-ray absorptiometry and lean mass index (lean mass [kg]/height [m]²) was calculated. We collected fasting venous blood for serum 25(OH) D and parathyroid hormone (PTH) at the baseline and again at the end of nineteen weeks of training. We assayed 25(OH)D and PTH using a chemiluminiscence analyser. (Roche model COBAS e 401). Intraassay and inter-assay coefficient of variation was <5% and <10% for 25(OH) D and <3% and <5% for PTH, respectively.

A trained instructor masked to the study design conducted a validated battery of tests for skeletal muscle function and cardiorespiratory fitness on the recruits with VDD at baseline and at the end of nineteen weeks of training.¹⁵ The battery of tests consisted of the following:

- Bent arm hang test:** This test was used to assess upper limb strength. The participants were asked to grasp a horizontal bar and hang with the arms bent at 90°, palms facing forward for as long as possible with the chin over the bar's plane. The time spent in this position, to the nearest tenth of a second, was recorded.
- Standing broad jump test:** This test was used to assess lower limb explosive strength. Individual participant stood behind a line with feet approximately shoulder's width apart and were asked to jump as far as possible with feet together. The result was recorded in centimetres
- 20-m shuttle run test:** This test was used to assess cardiorespiratory fitness. Batches of ten participants were asked to run between two lines 20 m apart, while keeping pace with audio signals emitted from a CD. The speed corresponding to the initial beep was 8.5 km/h and increased by 0.5 km/h every 1 min (1 min equals one stage). Participants were instructed to run in a straight line, to turn around on completing a shuttle and to pace themselves in accordance with the audio signals. The test was considered complete when the participant failed to reach the end lines with the audio signals on two consecutive occasions or stopped because of fatigue. Maximal oxygen intake $VO_2 \text{ Max}$ (Y, ml/kg/min) was derived from the speed (X, km/h) corresponding to that stage ($\text{speed} = 8 + 0.5 \text{ stage}$)

no) and age (A, year) using the formula $Y = 31.025 + 3.238X - 3.248A + 0.1536AX$.¹⁶

Statistical analysis

Statistical analysis was performed with Microsoft Excel. Continuous variables were expressed as mean $\pm$ SD (95% confidence interval). Changes in various parameters from the baseline in each group were analysed by paired 't' test, and difference between groups were analysed with student's 't' test. Of the forty-five participants assigned to each group, data of 43 in group I and 37 in group II were analysed. The missing data (n = 10) was because of absence for a follow up test and sample decay. A p value of <0.05 was considered significant.

Results

We screened two hundred and twenty three entry-level male recruits in the zero week of their training. Among the participants, 40.3% (90/223) had VDD (Fig. 1). The baseline characteristics of group I (cases) and II (control) are depicted in Table 1. At baseline, there was no difference in the parameters of strength and cardiorespiratory fitness in the two groups.

At the end of nineteen weeks, there was significant increase in serum levels of 25(OH) D and fall in serum PTH in both the groups (Tables 2 and 3). Participants in group I has shown significantly higher increase in serum levels of 25(OH) D levels and significantly higher decrease in levels of serum PTH compared to participants in group II (Table 4).

There were no significant changes in parameters of muscle strength in both the groups from baseline after nineteen weeks (Tables 2 and 3). However, both the groups had improved scores for the bent arm hang test.

VO2 max scores showed significant improvement in both groups (Tables 2 and 3); however, the difference between the groups was not significant (Table 4).

Discussion

We studied the effect of Vitamin D supplementation on physical performance in healthy young Indian men (military recruits) with VDD who were undergoing rigorous physical training during summer months. The prevalence of VDD in the study participants was 40.3%, which is lower than that reported in the literature.⁵

At the end of the study period, both the groups showed a significant improvement in the serum 25(OH) D levels (Tables 2 and 3). Increase in the control group (group II) is attributed to physical training. Basic military training involves rigorous outdoor training activities until 1200 h everyday. Melanin in skin, latitude, area of skin exposed, the zenith angle of the sun and duration of sun exposure are determinants of cutaneous synthesis of vitamin D.⁶ In a study on the effect of dose range of simulated sun exposure in South Asian participants at Manchester, UK, 53.5° N, participants who received ≥ 1.5 sun

Fig. 1 – A flow diagram of participants. VDD, vitamin D deficiency; 25(OH) D, 25 hydroxy vitamin D.

exposure doses (equivalent of 45 min of unshaded sun light exposure) over 35% of skin, three times a week for six weeks achieved a mean rise of 25(OH) D level of 15.7 ± 5.7 ng/ml.^{17,18} A year long study was conducted at Tirupati, India (13.40° N, 77.2° E), observing the effect of sunlight exposure to convert 7-dehydrocholesterol stored in borosilicate ampoules to pre-vitamin D3 and its photoproducts. The researchers found that at that latitude exposure to sunlight between 11 AM and 2 PM promoted vitamin D production in the skin throughout the year.¹⁹ Marwaha et al. studied the impact of sun exposure at New Delhi, India (28.61° N), during summer months. School children playing between 11 am and 12 noon during March–June and September–October with 15%–30% body surface area exposed to sunlight for a period of 4 weeks were able to increase serum 25(OH)D levels by 3.5–4.9 ng/ml.²⁰ The participants in the group II of our study had mean rise in serum 25(OH)D of 17.3 ± 3.5 ng/ml, which was because of daily exposure of 21% of the body surface area to sunlight until 1200 h for nineteen weeks. In a study on school children (age 10–14 years) majority with VDD, the authors randomized the children to three groups; no intervention, 200 ml milk fortified with 600 IU daily and 200 ml milk with 1000 IU daily. At the end of twelve weeks, the percentage of children with vitamin D above 20 ng/ml was 5.9%, 69.95% and 81.11%, respectively.²¹ The mean rise of serum 25(OH) D level (25.8 ± 7.1 ng/ml) in the group I was higher because of the combined effect of sun exposure and vitamin D supplementation (Table 4).

At the end of the study period, there was a significant improvement in VO2 max in both the groups when compared with baseline. Cardiorespiratory fitness reflects the ability of the body to work continuously for extended period. Factors influencing cardiovascular fitness include heredity, age,

Table 1 – Baseline parameters of participants in the group I (suppl group) and group II (Control).

Parameter	Group I (n = 43) Mean $\pm$ SD (95% CI)	Group II (n = 37) Mean $\pm$ SD (95% CI)	P Value
Age (years)	20.7 $\pm$ 1.5 (20.2–21.2)	21.1 $\pm$ 1.4 (20.7–21.6)	0.13
Weight (kg)	58.1 $\pm$ 4.6 (56.7–59.5)	59.3 $\pm$ 4.8 (57.7–60.9)	0.27
BMI (kg/m ²)	19.5 $\pm$ 1.6 (19.0–20.0)	20.14 $\pm$ 1.4 (19.7–20.6)	0.05
Lean mass index (kg/m ²)	17.1 $\pm$ 1.3 (16.8–17.5)	17.6 $\pm$ 1.2 (17.2–18.0)	0.39
25(OH)D (ng/ml)	13.0 $\pm$ 3.6 (11.9–14.1)	14.4 $\pm$ 2.1 (13.7–15.1)	0.05
Serum PTH (pg/ml)	44.2 $\pm$ 12.3 (42.3–48.0)	49.3 $\pm$ 18.6 (43.1–55.5)	0.17
Bent arm hang test (sec)	72.0 $\pm$ 16.9 (66.8–77.2)	73.6 $\pm$ 18.4 (67.6–79.9)	0.66
Broad jump (cm)	210.2 $\pm$ 17.6 (204.8–215.4)	213.9 $\pm$ 14.4 (209.0–218.7)	0.31
VO ₂ max (ml/kg/min)	76.7 $\pm$ 8.3 (74.1–79.3)	76.0 $\pm$ 8.5 (73.1–78.8)	0.72

BMI, body mass index; 25(OH) D, 25 hydroxy-vitamin D; PTH, parathyroid hormone; VO₂ max, maximal oxygen uptake; SD, standard deviation; CI, confidence interval.

Table 2 – Comparison of vitamin D levels and outcome of physical fitness test in the group I (at the end of nineteen weeks).

Parameter	Baseline Mean $\pm$ SD (95% CI)	Nineteen weeks Mean $\pm$ SD (95% CI)	P value
25(OH)D (ng/ml)	13.0 $\pm$ 3.6 (11.9–14.1)	40.3 $\pm$ 6.9 (37.9–42.7)	<0.005
Serum PTH (pg/ml)	44.2 $\pm$ 12.3 (42.3–48.0)	30.1 $\pm$ 11.0 (26.4–33.9)	<0.005
Bent arm hang test (sec)	72.0 $\pm$ 16.9 (66.8–77.2)	79.4 $\pm$ 18.0 (73.8–84.9)	0.05
Broad jump (cm)	210.2 $\pm$ 17.6 (204.8–215.4)	212.5 $\pm$ 15.8 (207.6–217.4)	0.41
VO ₂ max (ml/kg/min)	76.7 $\pm$ 8.3 (74.1–79.3)	86.4 $\pm$ 6.7 (84.3–88.4)	<0.005

25(OH) D, 25 hydroxy-vitamin D; PTH, parathyroid hormone; VO₂ max, maximal oxygen uptake; SD, standard deviation; CI, confidence interval.

Table 3 – Comparison of vitamin D levels and outcome of physical fitness test in the group II (n = 37).

Parameter	Baseline Mean $\pm$ SD (95% CI)	Nineteen weeks Mean $\pm$ SD (95% CI)	P value
25(OH) D (ng/ml)	14.4 $\pm$ 2.1 (13.7–15.1)	31.7 $\pm$ 5.2 (30.0–33.4)	<0.005
Serum PTH (pg/ml)	49.3 $\pm$ 18.6 (43.1–55.5)	44.5 $\pm$ 13.6 (39.9–49.0)	<0.005
Bent arm hang test (sec)	73.6 $\pm$ 18.4 (67.6–79.9)	80.9 $\pm$ 17.2 (75.2–86.6)	0.09
Broad jump (cm)	213.9 $\pm$ 14.4 (209.0–218.7)	219.0 $\pm$ 15.1 (214.0–224.0)	0.39
VO ₂ max (ml/kg/min)	76.0 $\pm$ 8.5 (73.1–78.8)	88.6 $\pm$ 6.6 (86.4–90.9)	<0.005

25(OH) D, 25 hydroxy-vitamin D; PTH, parathyroid hormone; VO₂ max, maximal oxygen uptake; SD, standard deviation; CI, confidence interval.

Table 4 – Comparison of mean of difference of vitamin D level and physical fitness test in groups I and II at nineteen weeks.

Parameter	Group I Mean $\pm$ SD (95% CI)	Group II Mean $\pm$ SD (95% CI)	P value
25 (OH) D (ng/ml)	25.8 $\pm$ 7.1 (23.3–28.2)	17.3 $\pm$ 3.5 (16.1–18.5)	<0.005
Serum PTH (pg/ml)	13.6 $\pm$ 11.4 (9.7–17.5)	4.80 $\pm$ 17.0 (–0.86 to 10.4)	0.01
Bent arm hang test (sec)	7.4 $\pm$ 14.6 (2.9–11.9)	7.1 $\pm$ 16.4 (1.6–12.6)	0.94
Broad jump (cm)	2.3 $\pm$ 14.8 (–2.3 to 6.8)	5.1 $\pm$ 13.1 (0.9–9.5)	0.35
VO ₂ max (ml/kg/min)	9.8 $\pm$ 8.8 (7.1–12.5)	12.7 $\pm$ 8.6 (9.8–15.6)	0.14

25(OH) D, 25 hydroxy-vitamin D; PTH, parathyroid hormone; VO₂ max, maximal oxygen uptake; SD, standard deviation; CI, confidence interval.

gender, body composition and level of physical activity.²² VO₂ max is the gold standard for assessment of cardiovascular fitness. The 20-m shuttle test is a well-validated indirect method of assessing VO₂ max.¹⁵ The role of serum 25(OH) D in maintenance of cardiorespiratory endurance has been studied in western population. A positive association was found in thirty-nine college students (20 men, 19 women; aged 23.6 $\pm$ 0.7 years) who were serially tested for 25(OH) D with simultaneous assessment of VO₂ max.¹¹

Valtuna et al. studied the association of levels of serum 25(OH)D and cardio respiratory fitness in European adolescents and found a positive association in male participants (n = 470) between levels of serum 25(OH) D and VO₂ max using the 20 m shuttle run test.¹² On the contrary, El Carson et al. in a cross-sectional study of adolescents (n = 1015) in Northern Ireland could not find similar association.¹⁴ In our study, the participants in both the groups showed rise in serum 25(OH)D and improvement in VO₂ max. The physical

training that recruits undergo primarily involve aerobic exercises (distance run, drills) and anaerobic exercises (sprints, push-ups, pull-ups, rope climbing). Aerobic exercises are known to improve cardiovascular endurance. Both the groups had dissimilar rise in serum 25(OH) D but a similar rise in VO₂ max. The physical training that the participants underwent explains better the rise in VO₂ max rather than attributing it to the rise in serum levels of serum 25(OH)D.

There was improvement in the results of the bent arm hang test (upper limb muscle strength), in both the groups, but no improvement was observed in parameters of lower limb muscle strength. The association of serum 25(OH) D and muscle strength has been extensively reviewed.⁹ In a randomised control trial (RCT) involving young Indian volunteers (24M/16F, mean age 31.5 ± 5.0 years) with VDD, six months of supplementation with cholecalciferol and calcium resulted in improvement in hand-grip strength, gastrocnemius-soleus muscle strength and improvement in walk distance (6 min walk test).²³ However, a larger study involving young Indian female volunteers (mean age 21.7 ± 4.4 y) by the same investigators failed to show similar benefit of vitamin D supplementation.²⁴ A recent systematic review and meta-analysis of thirty RCTs involving 5615 individuals (mean age: 61.1 years) showed a small but significant positive effect of vitamin D supplementation in elderly (age > 65 years) compared with younger participants.²⁵ Selection process for recruit training includes standard physical parameters. Participants in the group I and II had no significant difference in lean mass and muscle strength at baseline. The intensity of resistance training and/or duration of resistance training (time per day) may have been too short to reveal improvement in muscle strength in either group.

The physical training individuals undergo to become a combat ready soldier is gruelling and aimed at improving cardiorespiratory endurance and muscle strength; hence, special attention is paid to the diet they consume. We attempted to answer the question whether administering vitamin D supplement to those with VDD would improve their physical performance. Our study suggests that 25(OH) D rises even in those not given supplement as outdoor training increases cutaneous synthesis of vitamin D. The improvement in physical fitness parameters are more likely an effect of physical training that the individuals undergo. The strength of our study was that the participants in both groups were comparable as to age, lean mass index and baseline parameters of physical fitness. We also confirmed adequacy of change in vitamin D and repeated the tests under the same observer blinded to the methodology to reduce interobserver differences. The limitations were the small sample size, lack of blinding of the control, high dropout rate in control and inability to distinguish the graded effect of levels of vitamin D if any on parameters of physical fitness.

Conclusion

Young men with VDD undergoing basic military training in summer months have sufficient improvement in serum 25(OH) D levels because of outdoor training and may not require vitamin D supplementation. Improvement in

cardiorespiratory endurance is more because of physical training rather than increase in serum 25(OH) D levels. Muscle strength remains unaffected by increase in serum 25(OH) D and short duration of physical training.

Conflict of interest

The authors have none to declare.

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