Research Article

Associations between vitamin D and pulmonary function in chronic spinal cord injury

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Context/Objective: Individuals with chronic spinal cord injury (SCI) have an increased risk of morbidity and mortality attributable to respiratory diseases. Previous studies in non-SCI populations suggest that vitamin D may be a determinant of respiratory health. Therefore, we sought to assess if lower vitamin D levels were associated with decreased pulmonary function in persons with chronic SCI.

Design: Cross-sectional study.

Setting: Veterans Affairs Medical Center.

Participants: 312 participants (260 men and 52 women) with chronic SCI recruited from VA Boston and the community participating in an epidemiologic study to assess factors influencing respiratory health.

Methods: Participants provided a blood sample, completed a respiratory health questionnaire, and underwent spirometry. Linear regression methods were used to assess cross-sectional associations between plasma 25-hydroxyvitamin D and spirometric measures of pulmonary function.

Outcome Measures: Forced expiratory volume in one second (FEV₁), forced vital capacity (FVC), and FEV₁/FVC.

Results: Adjusted and unadjusted for a number of confounders, there was no significant association between plasma vitamin D levels and FEV₁, FVC, or FEV₁/FVC. For example, in fully adjusted models, each 10 ng/ml increase in vitamin D was associated with a 4.4 ml (95%CI -64.4, 73.2, P = 0.90) ml change in FEV₁.

Conclusion: There was no significant cross-sectional association between plasma vitamin D and FEV₁, FVC, or FEV₁/FVC in this cohort of individuals with chronic SCI.

Keywords: Vitamin D, Pulmonary function, Spinal cord injury

Introduction

Respiratory illnesses remain a common cause of morbidity and mortality in persons with chronic spinal cord injury (SCI).¹⁻⁴ We previously reported that in a VA Boston based chronic SCI cohort studied between 1994 and 2006, that there was a significant linear inverse relationship between %-predicted forced expiratory volume in one second (FEV₁) with greater mortality,⁵ cardiopulmonary hospitalization risk,⁶ and

chest illness risk,⁷ independent of level and severity of SCI. These findings demonstrate the importance of identifying modifiable factors that influence pulmonary function in SCI.

Vitamin D's role in respiratory health has been increasingly examined. Vitamin D deficiency has been associated with an increased risk of asthma,⁸⁻⁹ chronic bronchitis,¹⁰ COPD,¹¹ and reduced pulmonary function.¹²⁻¹³ For example, vitamin D deficiency has been associated with a more rapid decline in FEV₁ in persons with more pack years of smoking,¹⁴ and vitamin D supplementation has been associated with

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an improved FEV₁ in patients with COPD.¹⁵ Previous studies have reported significant cross-sectional associations between lower vitamin D levels and reduced FEV₁ and forced vital capacity (FVC).^{12–13,16–18} However, other studies support little or no relationship between vitamin D levels and reduced pulmonary function,¹⁹ COPD,²⁰ or asthma.^{21–22} Vitamin D deficiency is common in the SCI population.^{23–24} Therefore, we examined the relationship between FEV₁, FVC, and FEV₁/FVC and plasma vitamin D levels in a chronic SCI cohort.

Methods

Study population

Between 8/2009 and 4/2015 we recruited 360 individuals in a study to identify factors associated with respiratory health among individuals with chronic SCI. Participants were recruited from patients receiving care at VA Boston, from the greater Boston area through advertisement, and by direct mail to persons who had received care at Spaulding Rehabilitation Hospital, Boston University Medical Center, members of the National Spinal Cord Injury Association, and subscribers to New Mobility Magazine. Individuals were eligible if they were 22 years of age or older, were 1 or more years post-injury, had no other neuromuscular disease, did not have a tracheostomy, were able to breathe without chronic ventilatory support, and were eligible regardless of etiology of SCI. The Institutional Review Board at VA Boston Healthcare System approved the protocol and informed consent was obtained.

Pulmonary function testing

Spirometry was based on the 1994 American Thoracic Society (ATS) standards²⁵ modified for use in SCI as we have described previously.^{26–27} Testing was done using a dry-rolling seal spirometer (CPL system, nSpire Health, Inc; Longmont, CO) in 299 (95.8%) subjects or a pneumotach spirometer (Eaglet, nSpire Health, Inc; Longmont, CO) in 13 (4.2%) subjects. Flow-volume and volume-time loops were displayed with a goal of at least three acceptable efforts from each participant. Short expiratory efforts (less than 6 seconds) and excessive back extrapolation are common in SCI, but we have demonstrated that FVC and FEV₁ are reproducible in this population.²⁷ Therefore, we accepted excessive back extrapolation and efforts less than six seconds if the effort was maximal with an acceptable flow-volume loop, and at least a 0.5-second plateau at RV. The highest values of FEV₁ and FVC from acceptable efforts were used. Percent-predicted

FEV₁ and FVC were calculated based on NHANES equations.^{28–29}

Vitamin D measurements

EDTA plasma was drawn and immediately delivered to the core blood research at our facility. Samples were centrifuged for 15 minutes at 2,600 rpm (1459 x g) at 4°C and stored at –80°C. Analysis of plasma 25-hydroxyvitamin D (25-OH vitamin D) was done at the Clinical & Epidemiologic Research Laboratory, Department of Laboratory Medicine at Children's Hospital in Boston by high performance liquid chromatography tandem mass spectrometry (HPLC-MS/MS). The assay is linear up to 100 ng/ml, and sensitive to 1 ng/ml. Day-to-day precision (%CV) at various levels of 25OHD ranged from 5.6% to 8.5%.

Potential confounders

Participants completed questionnaires on respiratory health, lifestyle factors, and medical history.³⁰ In addition to age, race sex, and height, *a priori* potential confounders, included body mass index (BMI), cigarette smoking status (current, former, never) and pack-years of smoking, marijuana smoking (current, former, never), SCI duration, level, and severity, current use of pulmonary medications (inhaled steroids, long-acting bronchodilators within 24 hours, or short-acting bronchodilators within 6 hours of testing, doctor diagnosed chronic obstructive pulmonary disease (COPD) or asthma, chest operation and chest injury history, and primary mobility mode (motorized wheelchair, wheelchair, use of cane/walker, or able to walk unassisted). Height was obtained by measuring the body length while in a supine position from top of the head to the heel. Self-reported height was used if severe contracture or bracing hindered measurement (n = 28). If required, wheelchairs were weighed with and without the participant, and weight was subtracted to determine the participant's weight. Self-reported weight was used for four participants. Body mass index was calculated from height and weight.

SCI level and severity was assessed by exam during the study visit and medical record review. Motor level and completeness of injury was categorized according to the American Spinal Injury Association Impairment Scale (AIS).³¹ Participants were classified as motor complete, no motor function below the neurological level (AIS A or B); AIS C (motor incomplete, motor function preserved below the neurological level, and more than half the key muscles below the neurological level not strong enough to overcome gravity); or AIS D (motor incomplete, motor function preserved below

the neurological level, and half or more of key muscles below the neurological level strong enough to overcome gravity). Participants were grouped into cervical motor complete (AIS A or B) and cervical AIS C, high-thoracic (T1-T6) motor complete (AIS A or B) and AIS C, others with T7 or below motor complete (AIS A or B) and AIS C, and all others (AIS D's).

Statistical analyses

We excluded participants without a detectable SCI level ($n = 3$), with a previous stroke history ($n = 2$), incomplete data collection ($n = 6$), for whom we were unable to obtain blood during the visit ($n = 6$), who had no acceptable spirometry ($n = 20$) or did not complete pulmonary function testing ($n = 6$), and those who had previous lung resection surgery ($n = 5$), leaving 312 participants. General linear models (PROC GLM, SAS 9.4; SAS Institute Inc, Cary, NC) were used to calculate mean (and 95% confidence interval) FEV₁, FVC, or FEV₁/FVC for vitamin D categories according to the 2011 Endocrine Society's Practice guidelines (vitamin D deficiency: 25-hydroxyvitamin D < 20 ng/mL; insufficiency: 21–29 ng/mL; sufficiency: 30–100 ng/mL).³² The significance of trends across the categories was assessed using the median value of vitamin D in each category. In linear dose-response models, betas and 95% confidence intervals were calculated per 10 ng/ml increase in vitamin D (PROC REG, SAS 9.4; SAS Institute Inc, Cary, NC). Basic models included adjustment for age, sex, race, and included height for FEV₁ and FVC. Each potential confounder (or group of confounders) was added to the basic model to determine their association with each of the outcomes. Fully adjusted models included all *a priori* potential confounders, and parsimonious adjusted models included all potential confounders that were statistically significantly associated with the outcome or changed the association between the outcome and vitamin D by more than 10% when added to the basic models. In sensitivity analyses, we adjusted our final models for laboratory batch to assess potential differences in the measurement of vitamin D over time.

Results

Characteristics of the population are presented in Table 1. The average age was 53.9 ± 14.1 years old, the majority of participants were male (83%) and white (87%), and most were current or former smokers (59%). Few persons in the cohort (2.9%) were severely vitamin D deficient (<10 ng/mL), but 24% had levels of ≥ 10 and <20 ng/mL, and 49% had levels of ≥ 20 but <30 ng/mL. Average percent-predicted FEV₁ and FVC were 77.6 ± 20.9 and 78.4 ± 20.2 , respectively,

Table 1 Characteristics of the 312 individuals with spinal cord injury included in the analyses.

Characteristic	Mean $\pm$ SD or Median (25–75%ile)
Age (yrs)	53.9 $\pm$ 14.1
Body mass index	27.3 $\pm$ 6.1
Injury duration (yrs)	17.4 $\pm$ 13.4
Pack years of smoking*	18.0 (5.0–37.2)
FEV ₁ (L)	2.8 $\pm$ 0.9
%-predicted FEV ₁	77.6 $\pm$ 20.9
FVC (L)	3.6 $\pm$ 1.1
%-predicted FVC	78.4 $\pm$ 20.2
FEV ₁ /FVC	0.77 $\pm$ 0.11
Total vitamin D (ng/mL)	25.6 $\pm$ 11.6
	N (%)
Males	260 (83.3)
Race	
White	274 (87.2)
African American	23 (7.4)
Other	15 (4.8)
Vitamin D status	
Deficient <20 ng/mL**	84 (27.0)
Insufficient (≥ 20 –<30 ng/mL)	153 (49.0)
Normal (≥ 30 ng/mL)	75 (24.0)
Level of injury	
Motor complete cervical & AIS C	76 (24.4)
Motor complete high thoracic & AIS C	42 (13.5)
Motor complete low thoracic & AIS C	62 (19.9)
All AIS D	132 (42.3)
Mobility mode	
Motorized wheelchair	60 (19.2)
Wheelchair	136 (43.6)
Walk with cane/walker	54 (17.3)
Walk unassisted	62 (19.9)
Cigarette smoking status	
Current	52 (16.7)
Former	132 (42.3)
Never	128 (41.0)
Marijuana smoking status	
Current	37 (11.9)
Former	39 (12.5)
Never	236 (75.6)
Current statin use	97 (31.1)
Any pulmonary medication use	19 (6.1)
Short-acting bronchodilator within 6 hours	3 (1.0)
Long-acting bronchodilator within 24 hours	13 (4.2)
Current inhaled/oral steroid use	16 (5.1)
Doctor diagnosed COPD or asthma	63 (20.2)
History of chest operation or injury	90 (28.9)

*in 184 current/former smokers.

**severely deficient (<10 ng/ml) $n = 9$ (2.9%).

and the average FEV₁/FVC was 0.77 ± 0.11 . Most participants (90%) had at least two acceptable expiratory efforts with values of FEV₁ and FVC within 200 ml. Twenty-two (7%) had at least two or more acceptable efforts but FEV₁ and FVC were not within 200 ml and 9 (3%) participants had one acceptable effort.

The associations between vitamin D and FEV₁ are shown in Table 2, with FVC in Table 3, and with the FEV₁/FVC ratio in Table 4. There was no suggestion

Table 2 Adjusted mean levels of FEV₁ (L) within categories of total vitamin D and association of FEV₁ (mL) and continuous total vitamin D (per 10 ng/mL) among 312 individuals with SCI.

N	Vitamin D Categories				β (95% CI) mL per 10 ng/mL	P-value
	Deficient <20 ng/mL	Insufficient (≥20–<30 ng/mL)	Normal (≥30 ng/mL)	P-for trend		
	84	153	75	312	312	312
Basic*	2.75 (2.58, 2.92)	2.73 (2.61, 2.86)	2.81 (2.63, 2.98)	0.65	–8.37 (–85.01,68.27)	0.90
Basic + BMI	2.76 (2.59, 2.93)	2.73 (2.61, 2.85)	2.80 (2.62, 2.98)	0.73	–9.24 (–84.9,66.42)	0.81
Basic + BDs + steroids	2.75 (2.58, 2.92)	2.74 (2.61, 2.86)	2.80 (2.62, 2.98)	0.69	–3.23 (–78.1,71.64)	0.93
Basic + LOI	2.77 (2.61, 2.92)	2.71 (2.60, 2.82)	2.84 (2.68, 3.00)	0.45	19.90 (–49.09,88.89)	0.57
Basic + mobility	2.80 (2.65, 2.96)	2.71 (2.60, 2.82)	2.80 (2.64, 2.96)	0.99	1.15 (–66.47,68.77)	0.97
Basic + LOI + mobility	2.77 (2.61, 2.92)	2.71 (2.60, 2.82)	2.84 (2.68, 3.00)	0.46	16.40 (–52.20,85.00)	0.61
Basic + COPD or asthma	2.76 (2.59, 2.93)	2.73 (2.61, 2.85)	2.81 (2.64, 2.99)	0.63	–3.32 (–76.82,70.18)	0.93
Basic + Chest operation	2.76 (2.59, 2.93)	2.73 (2.60, 2.85)	2.82 (2.64, 2.99)	0.62	–4.92 (–79.60,69.76)	0.90
Basic + smoking	2.77 (2.60, 2.94)	2.73 (2.61, 2.85)	2.80 (2.63, 2.98)	0.77	–11.70 (–86.77,63.37)	0.76
Basic + marijuana	2.76 (2.59, 2.93)	2.73 (2.61, 2.85)	2.81 (2.63, 2.98)	0.68	–6.27 (–80.75,68.21)	0.87
Fully adjusted	2.81 (2.66, 2.96)	2.69 (2.58, 2.80)	2.83 (2.67, 2.99)	0.77	4.43 (–64.37,73.23)	0.90
Parsimonious adjusted**	2.79 (2.64, 2.95)	2.69 (2.59, 2.80)	2.84 (2.69, 3.00)	0.53	13.00 (–54.42,80.42)	0.70

*Adjusted for age, sex, race, and height.

**Adjusted for age, sex, race, height, smoking status and pack-years, marijuana smoking status, BMI, doctor diagnosed COPD or asthma, current use of long-acting bronchodilators, level of injury, and wheelchair use.

of an association between categorical or continuous measures of vitamin D with any of the measures of pulmonary function. In fully adjusted models, each 10 ng/mL increase in 25-OH vitamin D was associated with a 4.43 mL (95%CI: –64.37, 73.23 mL; $P = 0.90$) increase in FEV₁, an 0.92 mL (95%CI: –83.75, 85.60 mL; $P = 0.98$) increase in FVC, and an 0.13 (95%CI: –0.80, 1.06; $P = 0.79$) increase in FEV₁/FVC. Effect sizes were slightly larger, but still not statistically significant (P -values of 0.70, 0.77, and 0.66 for each 10 ng/mL increase in 25-OH vitamin D with FEV₁, FVC, and FEV₁/FVC, respectively) in parsimonious models that only were adjusted for age, sex, height (for FEV₁ and

FVC only), race, smoking status and pack-years, marijuana smoking status, BMI, doctor diagnosed COPD or asthma, current use of long-acting bronchodilators, level of injury, and primary mobility mode (dichotomized into wheelchair vs walking aided or unaided). In sensitivity analyses, adjusting for laboratory batch had no impact on the interpretation of any the final models (data not shown).

Discussion

In this cross-sectional study in persons with chronic SCI, we found no associations between plasma vitamin D levels and FEV₁, FVC, or FEV₁/FVC. Several studies

Table 3 Adjusted mean levels of FVC (L) within categories of total vitamin D and association of FVC (mL) and continuous total vitamin D (per 10 ng/mL) among 312 individuals with SCI.

N	Vitamin D Categories				β (95% CI) mL per 10 ng/mL	P-value
	Deficient <20 ng/mL	Insufficient (≥20–<30 ng/mL)	Normal (≥30 ng/mL)	P-for trend		
	84	153	75	312	312	312
Basic*	3.59 (3.38, 3.80)	3.61 (3.45, 3.76)	3.60 (3.38, 3.82)	0.96	–16.4 (–110.48,77.68)	0.73
Basic + BMI	3.59 (3.38, 3.81)	3.60 (3.45, 3.76)	3.59 (3.37, 3.82)	1.00	–19.3 (–114.56,75.96)	0.69
Basic + BDs + steroids	3.59 (3.38, 3.81)	3.60 (3.45, 3.76)	3.59 (3.37, 3.82)	0.99	–18.1 (–112.57,76.37)	0.71
Basic + LOI	3.59 (3.41, 3.78)	3.57 (3.44, 3.71)	3.66 (3.46, 3.85)	0.62	21.4 (–61.7,104.5)	0.61
Basic + mobility	3.65 (3.46, 3.83)	3.57 (3.44, 3.71)	3.60 (3.41, 3.79)	0.76	–3.82 (–85.75,78.11)	0.93
Basic + LOI + mobility	3.60 (3.41, 3.78)	3.57 (3.44, 3.71)	3.66 (3.46, 3.85)	0.65	16.8 (–66.11,99.71)	0.69
Basic + COPD or asthma	3.59 (3.38, 3.80)	3.60 (3.45, 3.76)	3.60 (3.38, 3.82)	0.96	–15.7 (–109.78,78.38)	0.74
Basic + Chest operation	3.59 (3.38, 3.81)	3.60 (3.44, 3.75)	3.61 (3.39, 3.83)	0.93	–16.4 (–110.48,77.68)	0.73
Basic + smoking	3.59 (3.38, 3.81)	3.60 (3.45, 3.76)	3.60 (3.38, 3.82)	0.98	–14.5 (–109.17,80.17)	0.76
Basic + marijuana	3.60 (3.39, 3.81)	3.60 (3.45, 3.75)	3.60 (3.37, 3.82)	0.98	–18.3 (–111.99,75.39)	0.70
Fully adjusted	3.65 (3.46, 3.83)	3.55 (3.42, 3.69)	3.64 (3.44, 3.83)	0.99	0.92 (–83.75,85.60)	0.98
Parsimonious adjusted**	3.62 (3.44, 3.81)	3.56 (3.43, 3.69)	3.65 (3.46, 3.84)	0.79	12.6 (–70.31,95.51)	0.77

*Adjusted for age, sex, race, and height.

**Adjusted for age, sex, race, height, smoking status and pack-years, marijuana smoking status, BMI, doctor diagnosed COPD or asthma, current use of long-acting bronchodilators, level of injury, and wheelchair use.

Table 4 Adjusted mean levels of FEV₁/FVC within categories of total vitamin D and association of FEV₁/FVC (%) and continuous total vitamin D (per 10 ng/mL) among 312 individuals with SCI.

	Vitamin D Categories				β (95% CI) mL per 10 ng/mL	P-value
	Deficient <20 ng/mL	Insufficient (≥20–<30 ng/mL)	Normal (≥30 ng/mL)	P-for trend		
N	84	153	75	312	312	312
Basic*	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.81)	0.33	0.32 (−0.65, 1.29)	0.52
Basic + BMI	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.80)	0.45	0.22 (−0.76, 1.20)	0.67
Basic + BDs + steroids	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.80)	0.36	0.41 (−0.55, 1.37)	0.40
Basic + LOI	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.80)	0.46	0.21 (−0.75, 1.17)	0.67
Basic + mobility	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.80)	0.49	0.21 (−0.74, 1.16)	0.66
Basic + LOI + mobility	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.80)	0.43	0.27 (−0.68, 1.22)	0.58
Basic + COPD or asthma	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.81)	0.29	0.35 (−0.57, 1.27)	0.46
Basic + Chest operation	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.81)	0.33	0.32 (−0.65, 1.29)	0.52
Basic + smoking	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.80)	0.54	0.06 (−0.89, 1.02)	0.90
Basic + marijuana	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.81)	0.31	0.33 (−0.64, 1.30)	0.51
Fully adjusted	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.80)	0.60	0.13 (−0.80, 1.06)	0.79
Parsimonious adjusted**	0.77 (0.75, 0.79)	0.76 (0.75, 0.78)	0.78 (0.76, 0.80)	0.50	0.20 (−0.70, 1.11)	0.66

*Adjusted for age, sex and race.

**Adjusted for age, sex, race, smoking status and pack-years, marijuana smoking status, BMI, doctor diagnosed COPD or asthma, current use of long-acting bronchodilators, level of injury, and wheelchair use.

have reported similar null findings in persons without SCI. These include Thuesen *et al.* (2015) who reported on 3,471 Danish adults during an initial visit or a five year follow-up visit.²¹ Kunisaki (2011) found no relationship between vitamin D deficiency and subsequent lung function decline in a subset of persons in the Lung Health Study 3 cohort assessed over six years.¹⁹ In a population based cross sectional study in the UK in 1,197 subjects, vitamin D levels were also not associated with FEV₁, FVC, and FEV₁/FVC.²⁰ In contrast, a significant cross-sectional positive relationship between vitamin D and FEV₁ and FVC was reported in a US cohort (n = 14,076) using NHANES III data,¹² in 6,789 British adults,¹³ in 18,507 participants in the Copenhagen City Heart Study and Copenhagen General Population Study,¹⁷ in ever smokers but not in never smokers among 1,220 participants in a population based study in Norway,¹⁸ and in 498 participants (most with COPD) in the Evaluation of COPD Longitudinally to Identify Predictive Surrogate Endpoints (ECLIPSE) study.¹⁶ Two studies also reported a significant association between lower levels of vitamin D and greater longitudinal change in FEV₁.^{17–18} The reasons for differences in the results between the positive and negative studies are uncertain.

Although modest in size compared to studies conducted in non-SCI populations, our study is the largest to date assessing health effects of vitamin D levels individuals with SCI, an important subgroup susceptible to the effects of factors contributing to a reduction in pulmonary function. In our cohort, although 27% of the subjects had vitamin D levels of 20 ng/mL or less and

49% had levels of ≥20 ng/mL to <30 ng/mL, few were severely deficient (≤10 ng/mL). In 100 persons with SCI admitted to an acute inpatient rehabilitation service described by Nemunaitis *et al.* (2010), 21% were severely deficient.²³ It is possible that if additional persons who were severely deficient had been included in the current study, a stronger cross-sectional relationship with reduced pulmonary function would have been observed. It is also possible that there is a threshold level above which pulmonary function is not impaired, which may only be detected in a study with larger numbers of individuals with very low vitamin D levels. Since we were only able to include participants well enough to travel to VA Boston and perform acceptable pulmonary function tests, it is also possible we excluded persons with the most reduced pulmonary function and lowest vitamin D levels.

Additionally, our results are cross-sectional and do not account for previous vitamin D levels or longitudinal variation in vitamin D based on season and variation in sunlight exposure. However, studies examining vitamin D levels over time have demonstrated reproducibility over periods ranging up to 3 years, suggesting a single determination approximates average levels.^{33–34}

As has been observed in some persons with COPD and who are severely deficient in vitamin D, it is possible that supplementation may be beneficial in maintaining respiratory health through biologic mechanisms other than influencing pulmonary function, such as by a reduction in respiratory tract infections.³⁵ Therefore, although our results suggest that plasma vitamin D levels in persons with chronic SCI are not associated

with impaired pulmonary function, longitudinal assessments, trials of supplementation, or studies in SCI populations with severely deficient vitamin D levels may demonstrate different effects.

Conclusion

Among individuals with chronic SCI with mainly deficient, insufficient, or normal levels of vitamin D, there was no significant cross-sectional association between plasma vitamin D and FEV₁, FVC, or FEV₁/FVC.

Disclaimer statements

Contributors None.

Conflicts of interest Authors have no conflict of interests to declare.

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