Relationship between vitamin D and lung function, physical performance and balance on patients with stage I-III chronic obstructive pulmonary disease

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Summary

Objectives: vitamin D is important for muscle function and it affects different aspects of muscle metabolism. This study aim to determine whether *serum* 25(OH) D levels are related to lung functions, physical performance and balance in patients with chronic obstructive pulmonary disease (COPD).
Methods: in 90 patients with COPD and 57 healthy controls lung function tests, physical performance tests (time up and go, gait velocity test, sit-to-stand test, isometric strength, isokinetic strength), static (functional reach test) and dynamic (time up and go) balance tests and the association of 25(OH)D levels with lung functions, physical performance and balance were evaluated.
Results: the COPD patients had significantly more deficit in physical function and balance parameters, and in dynamic balance test ($p<0.005$). Isokinetic knee muscle strength (flexor and extensor) in COPD patients was significantly lower than in the controls ($p<0.05$); FEV1 ($p=0.008$), FVC ($p=0.02$), FEV1/FVC ($p=0.04$), TLC ($p=0.01$) were lower in COPD patients with vitamin D deficiency [25(OH) D less than 15ng/mL] than in COPD patients without vitamin D deficiency. Hand grip test ($p=0.000$) and isokinetic knee muscle strength (flexor and extensor) ($p<0.05$) were also lower in COPD patients with vitamin D deficiency. Vitamin D deficiency was more pronounced in patients with stage III COPD ($p<0.05$).
Conclusion: patients with COPD had worst physical functioning, poor balance and less muscle strength. Severe disturbed lung and peripheral muscle functions are more pronounced in COPD patients with vitamin D deficiency.

Keywords: chronic obstructive pulmonary disease, vitamin D deficiency, muscle function.

Introduction

Patients with chronic obstructive pulmonary disease (COPD) complain of dyspnea on exertion and reduced exercise capacity. Pulmonary and extrapulmonary factors play a role in reduced exercise capacity. Especially, peripheral muscle dysfunction, independent of lung function, contributes significantly to reduced exercise capacity in these patients.[1,2]

Vitamin D is important for muscle function and it may affect different aspects of muscle metabolism.[3] A positive association between vitamin D and muscle strength or lower extremity function in elderly people has been described.[2] Similarly, vitamin D levels were positively associated with lung function.[4,5] Therefore, vitamin D deficiency can increase the susceptibility to psychological stress. Psychological stress can increase oxidative stress and modify host response to other inflammatory oxidative toxins such as smoke and air pollutants. These factors that can modify oxidative toxicity may have additive or multiplicative effects on lung function.[6]

Lower food intake, inactivity, reduced capacity of aging skin for vitamin D synthesis, absence of sun exposure, and increased catabolism by glucocorticoids may all contribute to a defective vitamin D status in patients with COPD.[7]

The aim of this study was to examine the physical performance and physical balance of patients with COPD through comparison with healthy controls using different objective measures, and to determine the influence of vitamin D status on lung functions and physical performance and balance in patients with COPD.

Material and methods

Study population

This cross-sectional study was performed in 90 patients with COPD and 57 age, gender and body mass index matched healthy controls. The study was carried out at the clinic of pulmonary medicine, Turgut Ozal Research Center of Inonu University from January 1, 2010, to December 31, 2010. The study protocol was approved by the ethics committee of the center, and informed consent was obtained from all participants. Ethical approval was obtained and all participants gave informed consent before enrollment.

Exclusion criteria were COPD exacerbations, chronic respiratory failure, presence of neurologic or psychiatric diseases, arthritis, primary cardiovascular diseases, right cardiac failure, diabetes mellitus and/or other systemic disorders, and patients with orthopedic problems in the lower extremities due to other reasons. Inclusion criteria were stage I-III COPD patients,[8] age between 40 and 75 years, ability to perform the tests, and no medical conditions that could interfere with participation in the present study.

Study design

The selected COPD patients and volunteers were examined and subsequently underwent tests measuring *serum* vitamin D levels, lung function, physical performance tests, physical balance tests.

Blood sampling and assays

Venous blood samples collected during the examination were centrifuged, aliquoted, and they were stored at -70°C until analysis. *Serum* 25(OH)D levels were measured by radioimmunometric assay (Recipe Chemical Instrument GmbH, Munich, Germany). Vitamin D deficiency was defined as 25(OH)D <15 ng/mL.[9]

Lung functions and respiratory muscle force

We measured forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC), total lung capacity (TLC), diffusing capacity (DLCO), maximal inspiratory (PImax) and expiratory (PEmax) pressures using an automated pulmonary function unit (VMAX Sensormedics 22C, USA) according to the recommendations issued by the American Thoracic Society,[10] and the reference values were those recommended by the European Respiratory Society.[11] DLCO was measured with the single-breath carbon monoxide diffusion method. PImax and PEmax were measured with an electronic transducer. PImax was measured near residual volume (RV), while PEmax was measured near TLC.

Physical performance and balance tests were assessed by objective measures that are described below in detail.

Physical performance tests

- The ‘timed up and go’ (TUG) test measures balance/physical mobility in a practical setting. It consisted of the subject rising from an armchair and walking 3 meters and returning to the chair to sit, while a researcher recorded the time.[12]
- Gait velocity test is a measure of gait velocity and function. Participants undergoing the test are instructed to walk a marked 50-foot distance, being timed so that their velocity may be calculated. Subjects are given an acceleration and deceleration zone of two steps before entering the timed distance and can walk at a self selected, usual pace.[12]
- Sit-to-stand Test (STST) was performed with a standard height (46 cm) chair without arm rests. The subjects held their arms stationary by putting their hands on their hips. Subjects were asked to complete the sitting and standing positions as correctly and as fully as they could, without using the arms for support while rising and sitting. The subjects were allowed to use rest periods to complete 1 min.[13]

Muscle strength tests

- Hand grip test measures the maximum isometric strength of the hand and forearm muscles. Muscle strength was measured as grip strength of the dominant hand using Jamar hold and squeeze dynamometer. The test was performed in a sitting position with the upper arms parallel to the trunk, the elbows bent at 90 degrees, and the forearm and hand in zero position. The test was performed 3 times and the mean value was recorded.[14]
- Isokinetic (dynamic) peak torque (PT) of the dominant extensor and flexor muscles in the knee (isokinetic muscle strength) was measured in a sitting position with a Biodex System 3 Pro (Biodex, Inc., Shirley, NY, USA). The isokinetic protocol consisted

of tests at two angular movement velocities of 90 and 180 degrees/sec at 10 rpm, with a 5-min rest period between tests. All tests were performed for concentric muscle strength as well, where the maximum PT (Nm) was recorded at each angular velocity.[15]

Balance tests

- The functional reach test is used as a test of static balance. The subject flexed one arm to an angle of 90°, while standing with legs about shoulder width apart. Subjects are asked to reach as far forward as possible along a meter stick mounted at shoulder height. The tip of the subject's middle finger in relation to the meter stick in both the starting position and ending position was evaluated. The distance between the starting and ending positions of the middle finger tip was recorded.[15]
- The 'timed up and go' (TUG) test.[12]

Statistical analysis

Statistical Package for Social Science (SPSS, Chicago, IL, USA) software version 17.0 was used for statistical evaluation. The independent sample *t*-test for normal distributed parameters and Mann-Whitney U test for non-normal distributed parameters was used to compare the groups. The data were expressed as the mean ± standard deviation for continuous variables and as frequency (in count) for categorical variables. Spearman's and Pearson analyses were used for correlation analysis. We assessed independent variables associated with lung function in patients with COPD, using stepwise multiple regression analysis. All p values of less than 0.05 were considered significant.

Results

The study was performed from December, 2009, to April, 2010, and from October, 2010, to April, 2011. 90 stage I-III COPD patients (86 male, 4 female) and 57 control subjects (51 male, 6 female) completed the study. Demographic characteristics, smoking history, lung functions and *serum* 25(OH)D levels of COPD and control groups are shown in Table I. Patients with COPD were divided into three groups, according to the results of the spirometry: stage I-mild COPD (n=15, 16.7%); stage II-moderate COPD (n=47, 52.2%); and stage III-severe COPD (n= 28, 31.1%).[8]

The scores of gait velocity test and TUG test in COPD patients were higher than those of control group (p=0.040 and p=0.000, respectively). The scores of STST, isokinetic strength tests and functional reach test were significantly lower in patients with COPD compared with those of the control group (p≤0.001, Table 2). There was no significant difference between the patients with COPD and healthy control group regarding hand grip test (p>0.05, Table 2).

TABLE 1 Demographic characteristics, smoking history, lung function and *serum* 25(OH)D levels of study subjects.

	COPD group (n=90)	Control group (n=57)	p value
Age (y)*	60.2±7.8	58.9±6.4	0.116
Gender**			
Female	4 (4.5%)	6 (10.5%)	0.154
Male	86 (95.5%)	51 (89.5%)	
BMI (kg/m²)*	26.08±4.3	27.24±3.10	0.08
Smoking history**			
Never smoker	8 (8.9%)	16 (28.1%)	0.017
Active smoker	40 (44.4%)	18 (31.6%)	
Passive smoker	1 (1.1%)	0	
Former-smoker	41 (45.6%)	23 (40.4%)	
Pack-years***			
Duration of smoking	42.7 (0-208)	22.3(0-64)	<0.0001
abstinence (years)*	4.7±8.17	4.3±9.0	0.48
Lung function			
FVC (L)*	3.2±88	4.2±87	<0.0001
FVC (%)	88.4±19.7	111.9±16	<0.0001
FEV_1 (L)*	1.819±681	3.3±66	<0.0001
FEV_1 (%)	62.5±20.6	110.2±15.8	<0.0001
FEV_1/FVC (%)	55.3±11.1	78.8±5.7	<0.0001
DLCO (mL/mmHg/dk)*	22.7±7.3	31.3±5.6	<0.0001
DLCO (%)	88.0±24.1	118±19.6	<0.0001
PImax (cmH_2O)*	56.3±22.9	56.5±24.8	0.95
PImax (%)	52.4±20.6	52.8±22.2	0.89
PEmax (cmH_2O)*	71±29	74.3±31	0.52
PEmax (%)	38±24.3	36.8±14.9	0.61
TLC (L)*	5.91±2.6	7.3±1.5	<0.0001
TLC (%)	96.7±50.7	115±19.6	<0.0001
25(OH)D (ng/mL)*	14.5±11.06	16.8±10	0.06

*mean ± SD
**n (%)
***median (minimum-maximum)

TABLE 2 Scores of physical performance tests and balance tests of study subjects.

	COPD group (n=90)	Control group (n=57)	p value
Physical performance tests			
Gait velocity test (s)	27.0±2.6	26.3±4.07	0.040
Sit-to-stand test	25.3±7.04	31.8±9.7	<0.0001

(continue)

TABLE 2 (Cont.) Scores of physical performance tests and balance tests of study subjects.

	COPD group (n=90)	Control group (n=57)	p value
Isometric strength test			
Hand grip test	32.8±9.0	33.9±9.5	0.659
Isokinetic strength test			
Knee extension peak torque at 90°/sec N.m	92.1±32.7	106.1±33.0	0.007
Knee flexion peak torque at 90°/sec N.m	44.8±18.0	52.0±19.7	0.012
Knee extension peak torque at 180°/sec N.m	58.0±17.8	68.6±19.6	0.001
Knee flexion peak torque at 180°/sec N.m	32.0±12.1	39.2±14.8	0.005
Balance tests			
TUG test (s)	7.4±1.11	6.8±1.9	<0.0001
Static balance (functional reach test)	23.7±5.8	27.1±6.4	0.001

*mean ± SD

Fifty four (60%) of the patients had vitamin D deficiency (mean 25(OH)D: 7.9±3.8 ng/mL) and in 36 (40%) patients' 25(OH)D levels were >15 ng/mL (mean 25(OH)D: 24.5±10.8 ng/mL).

FVC, FEV_1, FEV_1/FVC, DLCO levels and TLC were found to be significantly lower in COPD patients with vitamin D deficiency (p≤0.05), whereas there was no difference between the COPD patients with and without vitamin D deficiency, according to PImax and PEmax (p>0.05) (Table 3).

TABLE 3 Lung function according to *serum* vitamin D levels in COPD patients.

	25(OH)D <15 ng/mL*	25(OH)D 15 ng/mL*	p value
FVC (L)	3.08±86	3.47±87	0.02
FEV_1 (L)	1.67±67	2.04±63	0.008
FEV_1/FVC (%)	53.2±11.4	58.5±9.9	0.04
DLCO mL/mmHg/dk	21.5±7.7	25.1±6.1	0.05
PImax (cmH_2O)	51.8±21.9	63.5±22.9	0.20
PEmax (cmH_2O)	70.3±29.7	72.1±28.4	0.6
TLC (L)	5.39±1.75	6.74±3.43	0.01

*mean ± SD

The scores of hand grip test (p=0.000) and isokinetic strength tests (p≤0.05) were found to be significantly lower in COPD patients with vitamin D deficiency, compared with those of COPD patients without deficiency (Table 4).

TABLE 4 Physical performance tests and balance tests according to *serum* vitamin D levels in COPD patients.

	25(OH)D <15 ng/mL*	25(OH)D 15 ng/mL*	p value
25 (OH)D (ng/mL)	7.8±4	24.5±10.8	<0.0001
Physical performance tests			
Gait velocity test (s)	27.1±2.8	26.8±2.4	0.07
Sit-to-stand test (s)	24.8±7.7	26.1±6	0.42
Isometric strength test			
Hand grip test	30±9.2	37.1±7	<0.0001
Isokinetic strength test			
Knee extension peak torque at 90°/sec N.m	85±29.7	102.9±34.5	0.01
Knee flexion peak torque at 90°/sec N.m	40.7±17.8	51.0±16.7	0.006
Knee extension peak torque at 180°/sec N.m	55±16.9	62.5±18.5	0.04
Knee flexion peak torque at 180°/sec N.m	30.4±11.5	34.5±12.8	0.15
Balance tests			
TUG test (s)	7.6±1	7.3±1	0.45
Static balance (functional reach test)	23±6.2	24.7±5.0	0.09

*mean ± SD

In stage III severe-COPD patients, vitamin D levels were detected to be significantly lower than in the other stages (p<0.05).

In multiple regression analyses, the independent predictors of FVC in COPD patients were advanced age, pack-years and knee extension peak torque at 90°/sec, whereas 25(OH)D levels had no independent effect. The independent predictors of FEV_1 in COPD patients were age, knee extension peak torque at 90°/sec and pack-years whereas 25(OH)D levels had no independent effect (Table 5). Age and pack-years were the independent predictors of FEV_1/FVC, whereas knee extension peak torque at 90°/sec and 25(OH)D levels had no independent effect.

25(OH)D levels positively correlated with hand grip test (r= 0.490; p=0.000), knee flexion peak torque at 90°/sec (r=0.285, p=0.006), FVC (r=0.237, p=0.025), FEV_1 (r=0.253, p=0.016), PImax (r=0.214, p=0.049), TLC (r=0.245, p=0.026), and knee extension peak torque at 90° (r=0.254, p=0.016) in COPD patients (Table 6).

Discussion

The present study demonstrated that results of physical performance tests (time up and go, gait velocity test, sit-to-stand test, isokinetic strength), static (functional reach test) and dynamic (time up and go) balance tests in pa-

TABLE 5 Effective independent variables on airflow rates in COPD patients.

	FVC L: 0.361		FEV$_1$ L: 0.314		FEV$_1$/FVC %: 0.159	
	β	p	β	p	β	p
Knee extension peak torque at 90°/sec N.m	0.316	0.000	0.273	0.002	–	>0.05
Age (y)	-0.318	0.000	-0.225	0.012	-0.771	0.000
Pack-years	-0.169	0.029	-0.286	0.000	-0.155	0.006
25(OH) D levels	–	>0.05	–	p>0.05	–	>0.05

TABLE 6 Relationship between *serum* vitamin D levels and physical performance tests, balance tests and lung function in COPD patients.

25 (OH)D		
	r	p
Physical performance tests		
Gait velocity test (s)	0.011	0.915
Sit-to-stand test (s)	0.168	0.113
Isometric strength test		
Hand grip test	0.490**	<0.0001
Isokinetic strength test		
Knee extension peak torque at 90°/sec N.m	0.254*	0.016
Knee flexion peak torque at 90°/sec N.m	0.285**	0.006
Knee extension peak torque at 180°/sec N.m	0.183	0.084
Knee flexion peak torque at 180°/sec N.m	0.149	0.160
Balance tests		
TUG test (s)	-0.158	0.138
Static balance (functional reach test)	0.198	0.061
Lung function		
FVC (L)	0.237*	0.025
FEV$_1$ (L)	0.253*	0.016
FEV$_1$/FVC (%)	0.169	0.110
DLCO mL/mmHg/dk	0.136	0.323
PImax (cmH_2O)	0.214*	0.049
PEmax (cmH_2O)	0.074	0.498
TLC (L)	0.245*	0.026

*correlation **strong correlation

tients with COPD were worse than those of controls. Lung functions were significantly lower in COPD patients with vitamin D deficiency than in COPD patients without vitamin D deficiency.

It is generally accepted that the combination of several factors, such as respiratory limitation, elevated oxidative stress, systemic inflammation, hypoxemia, frequent steroid intake, age, inactivity, malnutrition and smoking are the main causes for deterioration in muscle function in COPD patients.[1,2] Patients with respiratory dysfunction are at risk of worsening gas exchange and of deterioration in functional status if they develop skeletal muscle weakness. Kim et al.[1] reported that both strength and endurance of skeletal muscle, limb muscles in particular, are reduced in patients with COPD and that these abnormalities are associated with attenuated exercise capacity.[1] Gosselink et al.[16] reported that lung function and peripheral muscle force are important determinants of exercise capacity in COPD.[16]

At present, there is no consensus on the optimal 25(OH)D concentration for health. Clinicians variably consider the presence of vitamin D deficiency at levels of 25(OH)D below 20 ng/mL or 30 ng/mL. In contrast, most clinicians agree that vitamin D deficiency is present at 25(OH)D levels less than 15 ng/mL.[9,17] In our study, 54 (60%) COPD patients had vitamin D deficiency (less than

15 ng/mL, mean 25(OH)D: 7.9±3.8 ng/mL). Lung function (FVC, FEV_1, FEV_1/FVC, DLCO, TLC) was significantly lower in COPD patients with vitamin D deficiency than in COPD patients without vitamin D deficiency, and 25(OH)D levels positively correlated with FVC, FEV_1, PImax and TLC. Vitamin D deficiency was more common in patients with stage III-severe COPD. Riancho et al.[18] reported a significant correlation between vitamin D and the time spent outdoors, suggesting that low exposure to sunlight was the reason for reduced concentrations of vitamin D.[18] However, one can speculate that higher levels of vitamin D are associated with better lung functions. The lungs do not grow in size after early adult life. However, it is likely that tissue remodeling and repair occur in the lungs throughout life. While the number of elastic fibers in the alveolar walls decrease with age, type III collagen levels increase with time.[19] It was speculated that vitamin D could influence lung function by influencing tissue remodeling and the synthesis of collagen.[20] Lehouck et al.[21] reported that in COPD patients with severe vitamin D deficiency at baseline vitamin D supplementation may reduce incidence of COPD exacerbations.[21]

In our study, the scores of hand grip test and isokinetic strength tests were found to be significantly lower in COPD patients with vitamin D deficiency. Vitamin D levels positively correlated with hand grip test and knee flexion and extension peak torque at 90°/sec in patients with COPD. Forli et al.[22] reported that vitamin D influences muscle function in patients with advanced pulmonary disease.[22] These authors showed that both calcitriol and PaO_2 were significantly associated with handgrip strength. Our results are in agreement with the results of that study. Taskapan et al.[23] showed that vitamin D supplementation improves muscle strength, functional ability and balance in chronic kidney disease (CKD) patients with vitamin D deficiency.[23] Whether prevention of vitamin D deficiency or adequate supplementation in COPD may reverse muscle strength is a burning question.

Vitamin D deficiency has been reported to affect the weight-bearing antigravity lower limbs muscles, which are necessary for postural balance and walking.[3] We demonstrated that balance (TUG and functional reach test) and physical performance (gait velocity test and STST) were worse in COPD patients, however, we could not demonstrate a relationship between *serum* 25(OH)D levels, balance and physical performance tests in patients with COPD. Other disease-related factors, such as hypoxemia, dyspnea and fatigue, can affect balance in patients with COPD.[24]

In our study, in multiple regression analyses, the independent predictors of FVC were age, knee extension peak torque at 90°/sec, and pack-years. The independent predictors of FEV_1 were age, knee extension peak torque at 90°/sec and pack-years. Age and pack-years were the independent predictor of FEV_1/FVC in COPD patients. COPD usually develops with advanced age and in the male gender. It has been established that limb muscles of older individuals are significantly smaller.[25] Alterations in muscle strength in COPD patients primarily involve the lower limb muscles, with quadriceps muscle strength being 20-30% lower in COPD patients.[16,26] The degree of reduced limb muscle strength correlates with the severity of COPD. Capacity of the muscle to maintain a certain force over time (endurance) of limb muscles is attenuated by about 30% in patients with moderate COPD, and poor muscle endurance in COPD correlates positively with FEV_1 and resting partial pressure of oxygen in arterial blood.[27,28] Our findings are consistent with the results of these studies.

The present study has several limitations. First, the sample size was relatively small. Second, we evaluated the association of *serum* 25(OH)D levels with lung and muscle functions in patients with COPD, however, we did not assess whether vitamin D supplementation can improve lung muscle and muscle functions in patients with COPD.

Conclusion

There is peripheral muscle dysfunction in COPD patients. Reduced lung and peripheral muscle functions are more pronounced in COPD patients with vitamin D deficiency.

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Resumo

Relação entre vitamina D e função pulmonar, desempenho físico e equilíbrio em pacientes em estágio I a III de doença pulmonar obstrutiva crônica.

Objetivos: a vitamina D é importante para a função muscular e afeta diferentes aspectos do metabolismo muscular. O objetivo é determinar se os níveis séricos de 25 (OH) D estão relacionados com as funções pulmonares, desempenho físico e equilíbrio em pacientes com doença pulmonar obstrutiva crônica (DPOC).
Métodos: em 90 pacientes com DPOC e 57 controles saudáveis, testes de espirometria, testes de desempenho (tempo de levantar e ir, teste de velocidade da marcha, teste *sit-to-stand*, força isométrica, força isocinética) e testes de

estática (teste de alcance funcional) e dinâmica (tempo de levantar e ir) de equilíbrio foram realizados; e foram avaliados a associação de níveis de 25 (OH) D com as funções pulmonares, desempenho físico e equilíbrio.

Resultados: os pacientes com DPOC apresentaram significativamente mais déficit nos parâmetros de função e equilíbrio físico, e no teste de equilíbrio dinâmico (p<0,005). Força muscular isocinética do joelho (flexores e extensores) em pacientes com DPOC foi significativamente menor do que nos controles (p<0,05); VEF1 (p=0,008), CVF (p=0,02), VEF_1/CVF (p=0,04), CPT (p=0,01) foram mais baixos em pacientes com DPOC e com deficiência de vitamina D [25 (OH) D menor do que 15 ng/ml] do que em pacientes com DPOC sem deficiência de vitamina D. Os resultados do teste da força de preensão manual (p=0,000) e força muscular isocinética do joelho (flexor e extensor) (p<0,05) também foram menores nos pacientes com DPOC e com deficiência de vitamina D. A deficiência de vitamina D foi mais pronunciada em pacientes em estágio III da DPOC (p<0,05).

Conclusão: pacientes com DPOC tiveram pior desempenho físico, falta de equilíbrio e menor força muscular. Perturbações graves das funções pulmonares e musculares periféricas são mais pronunciadas em pacientes com DPOC e com deficiência de vitamina D.

Palavras-chave: doença pulmonar obstrutiva crônica, deficiência de vitamina D, função muscular.

References

1. Kim HC, Mofarrahi M, Hussain SNA. Skeletal muscle dysfunction in patients with chronic obstructive pulmonary disease. Int J Chron Obstruct Pulmon Dis. 2008;3:637-58.
2. Janssens W, Lehouck A, Carremans C, Bouillon R, Mathieu C, Decramer M. Vitamin D beyond bones in chronic obstructive pulmonary disease. Am J Respir Crit Care Med. 2009;179:630-6.
3. Russell JA. Osteomalacic myopaty. Muscle Nerve. 1994;17:578-80.
4. Koechlin C, Maltais F, Saey D, Michaud A LeBlanc P, Hayot M, Prefaut C. Hypoxemia enhances peripheral muscle oxidative stres in chronic obstructive pulmonary disease. Thorax. 2005;60:834-41.
5. Black PN, Scragg R: Relationship between *serum* 25-hydroxyvitamin D and pulmonary function in third national health and nutrition examination survey. Chest. 2005;128:3792-8.
6. Wright RJ, Cohen RT, Cohen S. The impact of stress on the development and expression of atopy. Curr Opin Allergy Clin Immunol. 2005;5:23-9.
7. Holick MF. Vitamin D deficiency. N Engl J Med. 2007;357:266-81.
8. Global Initiative for Chronic Obstructive Lung Disease. Global strategy for the diagnosis, management and prevention of chronic obstructive pulmonary disease 2001, 2006, 2009(update). Availale from://www.goldcopd.com.
9. National Kidney Foundation. K/DOQI clinical practice guidelines for bone metabolism and disease in chronic kidney disease. Am J Kidney Dis. 2003;42(4 Suppl 3):S1-201.
10. American Thoracic Society: Standartized lung function testing: 1987 Update. Am Rev Respir Dis. 1987;136:1285-98.
11. Quanjer PH, Tammeling GJ, Cotes JE, Pederson OF, Peslin R, Yernault JC. Lung volumes and forced ventilatory flows. Report Working Party Standardization of Lung Function Tests, European Community for Steel and Coal. Official Statement of the European Respiratory Society. Eur Respir J Suppl 1993; 16: 5: 40.
12. Hayes KW, Johnson ME. Measures of adult general performance Tests. Arthritis Rheum. 2003;49(Suppl 5):S28-S42.
13. Bohannon RW, Smith J, Hull D, Palmeri D, Barnhard R. Deficits in lower extremity muscle and gait performance among renal transplant candidates. Arch Phys Med Rehab. 1995;76:547-51.
14. Mengshoel AM, Forre O, Komnaes HB. Muscle strength and aerobic capacity in primary fibromyalgia. Clin Exp Rheumatol. 1990;8:475-9.
15. Cetin N, Bayramoglu M, Aytar A, Surenkok O, Yemisci OU. Effects of lower-extremity and trunk muscle fatigue on balance. Open Sports Med J. 2008;2:16-22.
16. Gosselink R, Troosters T, Decramer M. Peripheral muscle weakness contributes to exercise limitation in COPD. Am J Respir Crit Care Med. 1996;153:976-80.
17. Andıran N, Çelik N, Akça H, Doğan G. Vitamin D deficiency in children and adolescents. J Clin Res Pediatr Endocrinol. 2012;4:25-9.
18. Riancho JA, Macias JG, Arco CD, Amado JA, Freijanes, Anton MA. Vertebral compression fractures and mineral metabolism in chronic obstructive lung disease. Thorax. 1987;42:962-6.
19. D'Errico A, Scarani P, Colosimo E, Spina M, Grigioni WF, Mancini AM. Changes in the alveolar connective tissue of the ageing lung: an immunohistochemical study. Virchows Arch A Pathol Anat Histopathol. 1989;415:137-44.
20. Dobak J, Grzybowski J, Liu FT, Landon B, Dobke M. 1,25-dihydroxyvitamin D3 increases collagen production in dermal fibroblasts. J Dermatol Sci. 1994;8:18-24.
21. Lehouck A, Mathieu C, Carremans C, Baeke F, Verhaegen J, Van Eldere J, High doses of vitamin D to reduce exacerbations in chronic obstructive pulmonary disease: a randomized trial. Ann Intern Med. 2012;156:105-14.
22. Forli L, Bjortuft O, Boe J. Vitamin D status in relation to nutritional depletion and muscllle function in patients with advanced pulmonary disease. Exp Lung Res. 2009;35:524-38.
23. Taskapan H, Baysal O, Karahan D, Durmus B, Altay Z, Ulutas O. Vitamin D and muscle strength, functional ability and balance in peritoneal dialysis patients with vitamin D deficiency. Clin Nephrol. 2011;76:110-6.
24. Ozalevli S, Ilgın D, Narin S, Akkoçlu A. Association between disease-related factors and balance and falls among the elderly with COPD: a cross-sectional study. Aging Clin Exp Res. 2011;23:372-7.
25. Lexell J. Human aging, muscle mass, and fiber type composition. J Gerontol A Biol Sci Med Sci. 1995;50:11-6.
26. Franssen FM, Broekhuizen R, Janssen PP, Wouters EF, Schols AM. Limb muscle dysfunction in COPD: effects of muscle wasting and exercise training. Med Sci Sports Exerc. 2005;37:2-9.
27. Serres I, Gautier V, Prefaut C, Varray A. Impaired skeletal muscle-endurace related to physical inactivity and altered lung funtion in COPD patients. Chest. 1998;113:900-5.
28. Hull AV, Harlaar J, Gosselink R, Hollander P, Postmus P, Kwakkel G. Quadriceps muscle endurance in patients with chronic obstructive pulmonary disease. Muscle Nerve. 2004;29:267-74.