Effects of Ionizing Radiation on Respiratory Function Tests and Blood Parameters in Radiology Staff

M Saygin¹, S Yasar², M Kayan², UG Balci³, K Öngel⁴

ABSTRACT

Aim: To evaluate pulmonary function tests and blood parameters and their relationship with socio-demographic data for radiology staff continuously exposed to ionizing radiation.

Subjects and Method: Thirty-eight personnel from Suleyman Demirel University Training and Research Hospital, Radiology Unit, were included in this study. Sociodemographic data were evaluated by a questionnaire that was developed by the researchers. Height and weight measurements were performed with a standard scale and meter. Routine blood parameters and spirometric lung function measurements of the cases were recorded. Statistical significances were determined by independent t-test, analysis of variance (ANOVA), bivariate correlation and Kruskal-Wallis tests using SPSS 18.0.

Results: The mean age was 32.42 ± 5.5 years; 19 patients (50%) were male and 19 patients (50%) were female. Body mass index (BMI) was calculated as 25.68 ± 0.47 for men and 24.58 ± 1.13 for women. Forced vital capacity (FVC), forced expiratory volume in the 1st second (FEV₁), peak expiratory flow (PEF) and maximum mid-expiratory flow (FEF₂₅₋₇₅) showed statistically significant differences between gender ($p < 0.01$). In addition, FEV₁ and FEF₂₅₋₇₅ also demonstrated statistically negatively significant difference with the type of task ($p < 0.05$). A statistically significant negative difference was found between FEF₂₅₋₇₅ value and time to start smoking ($p < 0.05$). Among FVC, FEV₁, PEF and FEF₂₅₋₇₅ values and alcohol usage, statistically significant positive difference was detected ($p < 0.05$). Statistically significant positive difference was found among FVC, PEF and FEF₂₅₋₇₅ values and sports activity ($p < 0.05$). According to BMI groups, statistically significant positive difference with FVC, FEV₁ and PEF values were found ($p < 0.05$). Statistically significant correlations were found among FVC value and haemoglobin level (Hgb), haematocrit level (Hct) and mean corpuscular volume (MCV), among FEV₁ value and Hgb, MCV, among PEF value and red blood cell count (RBC), Hgb, Hct, MCV, red cell distribution width (RDW), and between FEF₂₅₋₇₅ value and MCV.

Conclusion: Although respiratory functions of radiology staff are affected by many factors, continuous exposure to ionizing radiation is one of the important parameters. Radiology staff should be informed about factors that negatively affect the respiratory functions.

Keywords: Ionizing radiation, radiation, radiology staff, respiratory function tests

Efectos de las Radiaciones Ionizantes en las Pruebas de Función Respiratoria y los Parámetros de la Sangre del Personal de Radiología

M Saygin¹, S Yasar², M Kayan², UG Balci³, K Öngel⁴

RESUMEN

Objetivo: Evaluar las pruebas de función pulmonar y parámetros de sangre y su relación con los datos sociodemográficos para el personal de radiología continuamente expuesto a la radiación ionizante.

Sujetos y método: Este estudio incluyó treinta y ocho miembros del personal de la Unidad de Radiología del Hospital de Docencia e Investigación de la Universidad Suleyman Demirel. Los datos sociode-

From: ¹Department of Physiology, Faculty of Medicine, Suleyman Demirel University, Isparta, Turkey, ²Department of Radiodiagnostics, Faculty of Medicine, Suleyman Demirel University, Isparta, Turkey, ³Department of Family Medicine, İzmir Tepecik Education and Research Hospital, İzmir, Turkey and ⁴Department of Family Medicine, Faculty of Medicine, İzmir Katip Çelebi University, İzmir, Turkey.

Correspondence: Dr M Saygin, Süleyman Demirel Üniversitesi Tıp Fakültesi, Fizyoloji Anabilim Dalı Çünür, Isparta, Turkey.
E-mail: mustafasaygin@sdu.edu.tr

mográficos se evaluaron mediante un formulario que fue desarrollado por los investigadores. Se realizaron mediciones de la altura y el peso con un metro y una escala estándar. Se registraron los datos de rutina sobre los parámetros de sangre y las mediciones de la función pulmonar espirométrica de los casos. La respectiva importancia estadística fue determinada mediante la prueba t independiente, análisis de varianza (ANOVA), correlación bivariada y pruebas de Kruskal-Wallis utilizando SPSS 18.0.

Resultados: *La edad promedio fue de 32.42 ± 5.5 años; 19 pacientes (50%) eran varones y 19 pacientes (50%) eran mujeres. El índice de masa corporal (IMC) se calculó como 25.68 ± 0.47 para los hombres y 24.58 ± 1.13 para las mujeres. La capacidad vital forzada (CVF), el volumen espiratorio forzado en el primer segundo (VEF_1), el flujo espiratorio máximo (FEM), y los valores del flujo espiratorio medio máximo ($FEMM_{25-75}$) mostraron diferencias negativas estadísticamente significativas entre géneros ($p < 0.01$). Además, el VEF_1 y el $FEMM_{25-75}$ también mostraron diferencias negativas estadísticamente significativas en relación con el tipo de la tarea ($p < 0.05$). Se halló una diferencia negativa estadísticamente significativa entre el valor de $FEMM_{25-75}$ y el tiempo del inicio del hábito de fumar ($p < 0.05$). Se detectó una diferencia positiva estadísticamente significativa entre los valores de CVF, VEF_1 , FEM y $FEMM_{25-75}$, y el hábito de consumir alcohol ($p < 0.05$). Se detectó una diferencia positiva estadísticamente significativa entre los valores de CVF, FEM y $FEMM_{25-75}$, y las actividades de deporte ($p < 0.05$). Según los grupos de IMC, se halló una diferencia positiva estadísticamente significativa entre los valores de CVF, VEF_1 , y los valores de FEM ($p < 0.05$). Se hallaron correlaciones estadísticamente significativas entre el valor de CVF y el nivel de la hemoglobina (Hgb), el nivel de hematocrito (Hct) y el volumen corpuscular medio (VCM); entre el valor de VEF_1 y Hgb, VCM; entre el valor de FEM, y el conteo de glóbulos rojos (CGR), Hgb, Hct, VCM, y la distribución de los glóbulos rojos; y entre el valor de $FEMM_{25-75}$ y VCM.*

Conclusión: *Aunque las funciones respiratorias del personal de radiología son afectadas por muchos factores, la exposición continua a la radiación ionizante es uno de los parámetros importantes. El personal de radiología debe ser informado acerca de los factores prevenibles que afectan negativamente las funciones respiratorias.*

Palabras claves: Radiación ionizante, radiación, personal de radiología, pruebas de la función respiratoria

West Indian Med J 2014; 63 (1): 41

INTRODUCTION

X-rays are a type of electromagnetic ionizing radiation used for diagnostic purpose in radiology due to their high penetration power and low specific ionization (1). Ionizing radiation, by transferring energy to the cells and tissues, starts biological events leading to a series of reactions ranging from cell interactions to biological damage (1–4).

Biological effects of radiation generated at the cellular level may occur within seconds but may also develop during a 20–30-year period (5). As a result of radiation exposure, cell death, degradation of DNA, development of malignancy and genetic damage can occur (6). Irradiation-induced damage can be repaired by the organism, can remain unrepaired or can be abnormally repaired (7).

Radiation workers are the people who are exposed to the highest amount of radiation in society. The effects of long-term intermittent exposure to low radiation doses and chronic irradiation may appear after many years, causing a series of fatal diseases and other negative effects. The reason for this may be related with not being able to repair the present damage until the next irradiation and therefore accumulation of the damage during these periods (2). Cancer may develop as

a result of an interaction of a single ionizing particle which was previously damaged and was unable to repair itself. In addition, hereditary disorders in the next generations can be found in these persons (8).

According to the basic law of radiobiology, sensitivity to radiation, ranked from the most sensitive to the most resistant is as follows: rapidly dividing, undifferentiated most sensitive cells, erythroblasts (erythrocyte main cells), intestinal crypt cells, primary sperm cells and epidermal basal cells. As cells are differentiated, despite continuing rapid proliferation, sensitivity decreases. Lymphocytes are non-dividing cells after passing into the blood circulation and although they are highly differentiated, they are sensitive to radiation (9).

During therapeutic and diagnostic medical procedures, the upper extremities of medical staff are especially highly exposed to X-rays.

In this study, radiology staff working in the Suleyman Demirel University Training and Research Hospital who are constantly exposed to ionizing radiation were subjected to the investigation of the relationship among ionizing radiation, pulmonary function and blood parameters.

SUBJECTS AND METHOD

Thirty-eight staff members from the Radiology Unit of Suleyman Demirel University Training and Research Hospital were included. Before the administration of the survey, staff members who agreed to participate were verbally informed about the content of the study. This was a cross-sectional study and all staff members working in the department were included. Sociodemographic data were evaluated by a questionnaire that was developed by the researchers. In this survey, demographic data, smoking, alcohol usage and exercise level were evaluated. Height and weight measurements were made with standard scales and measuring cylinder. Body mass index (BMI) was calculated as weight in kilograms divided by the square of the height in metres. Personal dosimetries were evaluated by Turkish Atomic Energy Agency (TAEA).

Spirometric measurements and complete blood tests of the staff were performed periodically. Respiratory functions of the staff participating in the study were taken with 120 B SİBELMED DATOSPIR mode spirometer. The spirometric measurements were recorded together with the survey data. Tests related to airway functions were:

1. Simple spirometric tests, vital capacity (VC)
2. Forced vital capacity: a) forced vital capacity (FVC), forced expiratory volume in the 1st second (FEV₁), maximum mid-expiratory flow (FEF_{25-75%}) and peak expiratory flow [PEF] (10).

Blood parameters of the staff participating in the study were measured by a complete blood count device and white blood cell count (WBC), red blood cell count (RBC), haemoglobin level (Hgb), haematocrit level (Hct), mean corpuscular volume (MCV), mean corpuscular haemoglobin concentration (MCHC), red cell distribution width (RDW) and platelet count (PLT) were recorded.

Statistical analysis was performed by SPSS 18.0 for Windows. Normal distribution of data and homogeneous variances were tested. For the statistical analysis, one way analysis of variance (ANOVA), independent *t*-test, bivariate correlation and Kruskal-Wallis tests were used.

RESULTS

In the study, 38 staff members (19 females and 19 males) from the Radiology Unit of Suleyman Demirel University Training and Research Hospital were included. Demographic characteristics of the staff, age ranges, working time in the Radiology Unit, marital status, weekly working hours and other findings are given in the Table.

According to the results provided by TAEA from the personal dosimetry readings, with two months intervals in a year, highest ionizing radiation dose was 11.85 mSv and lowest dose was 0.1 mSv. In the study, the arithmetic mean of the lowest and highest exposure dose was found out as 0.75 mSv and the doses above this mean value was considered as high doses and below this mean value was considered as low doses. Thus, it was found that 31 of the radiology staff were exposed to ionizing radiation with doses lower than 0.75 mSv, while seven of

Table: Demographic features of the radiology staff

Characteristics		n	%
Gender	Female	19	50
	Male	19	50
Marital status	Single	8	21.1
	Divorced	1	2.6
	Separated	1	2.6
	Married	28	73.7
Task	Doctor	14	36.8
	Nurse	6	15.8
	Technician	18	47.4
SDU radiology tenure	1–5 years	27	71.1
	6–10 years	4	10.5
	11–15 years	6	15.8
	16–20 years	1	2.6
Working time	30–40 hours	15	39.5
	Over 40 hours	23	60.5
Smoking	No	27	71.1
	Daily 1–2	2	5.3
	Daily 3–5	2	5.3
	Daily 5–10	3	7.9
	Daily 10–20	2	5.3
	Daily 20 ⁺	2	5.3
Alcohol usage	No	30	78.9
	Years 1–2	5	13.2
	Monthly 3–5	3	7.9
Sports activities	None	25	65.8
	Monthly 1–2 hours	6	15.8
	Weekly 1–2 hours	4	10.5
	At least 3 days	1	2.6
	Every day regularly	2	5.3
Body mass index	Low weight	2	5.2
	Nomal	20	52.2
	Pre-obese	15	30.1
	extremely obese	1	2.6
Respiratory complaints	Dyspnoea	2	5.3
	Dyspnoea with effort	6	15.8
	Allergic rhinitis	6	15.8
	Wheezing	1	2.6
	Hacking cough	3	7.9
	Expectorate	4	10.5
	Other	3	7.9
	Asymptomatic	13	34.2
Anaemia	Yes	8	21.1
	No	30	78.9
Iron deficiency treatment	Yes	2	5.3
	No	36	94.7

the radiology staff were exposed to the doses higher than 0.75 mSv in a year.

Mean values of the respiratory function test parameters were evaluated. Results were as follows; FVC (L) 3.94 ± 0.80 (min: 2.61 – max: 6.07), FEV₁ (L) 3.18 ± 0.69 (min: 1.98 – max: 4.89), FEV₁/FVC (%) 80.64 ± 5.93 (min: 65.94 – max: 87.97), PEF (L/s) 6.47 ± 2.29 (min: 2.66 – max: 11.69), FEF₂₅₋₇₅ (L/s) 3.22 ± 0.94 (min: 1.28 – max: 4.89).

Moreover, mean values of the parameters were evaluated according to gender. Mean values of the respiratory function test parameters for female staff were as follows: FVC (L) 3.37 ± 0.44 (min: 2.61 – max: 4.00), FEV₁ (L) 2.69 ± 0.46 (min: 1.98 – max: 3.35), FEV₁/FVC (%) 79.59 ± 7.08 (min: 65.94 – max: 87.97), PEF (L/s) 4.67 ± 1.22 (min: 2.66 – max: 7.00), FEF₂₅₋₇₅ (L/s) 2.68 ± 0.77 (min: 1.28 – max: 3.76). For male staff: FVC (L) 4.42 ± 0.73 (min: 3.46 – max: 6.07), FEV₁ (L) 3.59 ± 0.58 (min: 2.83 – max: 4.89), FEV₁/FVC (%) 81.53 ± 4.77 (min: 70.36 – max: 87.39), PEF (L/s) 8.00 ± 1.81 (min: 4.21 – max: 11.69), FEF₂₅₋₇₅ (L/s) 3.68 ± 0.84 (min: 2.05 – max: 4.89).

Mean values of blood parameters for all staff were recorded as: WBC ($10^3/\mu\text{L}$) 7.88 ± 2.30 (min: 5.50 – max: 15.40), WBC ($10^3/\mu\text{L}$) 4.80 ± 0.58 (min: 2.91 – max: 5.80), Hgb (g/dL) 14.36 ± 1.89 (min: 9.20 – max: 17.70), Hct (%) 41.78 ± 5.69 (min: 26.20 – max: 55.50), MCV (fL) 86.91 ± 5.21 (min: 77.20 – max: 95.10), MCHC (g/dL) 33.86 ± 3.27 (min: 16.50 – max: 37.20), RDW (%) 13.57 ± 1.08 (min: 12.20 – max: 16.40) and PLT ($10^3/\mu\text{L}$) 233.77 ± 53.85 (min: 135 – max: 348).

According to gender, mean values of blood parameters for female staff were: WBC ($10^3/\mu\text{L}$) 7.63 ± 1.61 (min: 5.50 – max: 10.70), RBC ($10^3/\mu\text{L}$) 4.61 ± 0.38 (min: 3.58 – max: 5.36), Hgb (g/dL) 13.40 ± 1.18 (min: 11.10 – max: 15.90), Hct (%) 39.32 ± 3.98 (min: 32.60 – max: 47.50), MCV (fL) 85.28 ± 5.14 (min: 77.20 – max: 92.80), MCHC (g/dL) 32.99 ± 4.27 (min: 16.50 – max: 35.80), RDW (%) 13.92 ± 1.15 (min: 12.40 – max: 16.40) and PLT ($10^3/\mu\text{L}$) 230 ± 50.06 (min: 135 – max: 324). Mean values of blood parameters for male staff were: WBC ($10^3/\mu\text{L}$) 8.12 ± 2.85 (min: 5.50 – max: 15.40), RBC ($10^3/\mu\text{L}$) 5.00 ± 0.69 (min: 2.91 – max: 5.80), Hgb (g/dL) 15.33 ± 2.00 (min: 9.20 – max: 17.70), Hct (%) 44.23 ± 6.16 (min: 26.20 – max: 53.50), MCV (fL) 88.53 ± 4.89 (min: 77.80 – max: 95.10), MCHC (g/dL) 34.73 ± 1.46 (min: 32.00 – max: 37.20), RDW (%) 13.22 ± 0.92 (min: 12.20 – max: 16.30) and PLT ($10^3/\mu\text{L}$) 237.55 ± 50.06 (min: 140 – max: 348).

Forced vital capacity (d:–,132), FEV₁ (d:–,171), PEF (d:–,068) and FEF₂₅₋₇₅ (d:–,169) values showed negatively statistically significant differences between gender ($p < 0.01$). In addition, FEV₁ (d:–,258) and FEF₂₅₋₇₅ (d:–,324) also demonstrated negatively statistically significant difference with the type of the task ($p < 0.05$). A statistically significant negative difference was found between FEF₂₅₋₇₅ (d:–,333) value and time to start smoking ($p < 0.05$). Between FVC (d:–,245), FEV₁ (d:–,301), PEF (d:–,299) and FEF₂₅₋₇₅ (d:–,331) values and alcohol usage, statistically significant positive difference was detected ($p < 0.05$). Statistically significant positive difference was found between FVC (d:–,280), PEF (d:–,382) and FEF₂₅₋₇₅ (d:–,239) values and physical activity ($p < 0.05$). According to BMI, statistically positive significant difference with FVC (d:–,324), FEV₁ (d:–,307) and PEF (d:–,411) values were found ($p < 0.05$). Statistically significant correlations were found among FVC value and Hgb, Hct, MCV;

among FEV₁ value and Hgb, MCV; among PEF value and RBC, Hgb, Hct, MCV, RDW; and between FEF₂₅₋₇₅ value and MCV.

DISCUSSION

In this study, pulmonary function tests and blood parameters of the radiology staff exposed to ionizing radiation were investigated. Blood cells that are sensitive to ionizing radiation have been evaluated in many studies. However, respiratory function tests of the radiology staff exposed to ionizing radiation have not been evaluated. The results of this study appear to be the first published data in this area.

Biological effects of radiation generated at a cellular level may occur within seconds and may also develop over a long period (20–30 years). These effects are: slow down or stop in cellular movements, delay or stop in growth, abnormalities in cellular metabolism and cell division [mitotic proliferation] (5). According to the hypothesis of “Radiobiology basic law” developed by Tribondeau Bergonie and in 1906, based on the biological effects of radiation, biological effects observed in irradiated cells are positively correlated with cell proliferation, but inversely proportional to the degree of differentiation (9, 11). Biological effects of radiation on radiology workers, most probably the professionals who are exposed to the highest amount of radiation, occur due to the intermittent exposure to low doses of irradiation for long-term periods. These chronic effects would be observed after many years and often cause a series of fatal diseases and other negative effects (8). For radiology staff, even protected from radiation, small doses of radiation show significant risks (12). In the present study, it was observed that parameters related with pulmonary functions and blood were affected by ionizing radiation.

Forced vital capacity, FEV₁, PEF and FEF₂₅₋₇₅ values showed significant difference according to gender. This result can be explained by the difference in lung volumes and capacities with age, height and gender (13).

Depending on specification of task at the radiology unit, staff was classified as nurses, technicians and doctors. According to the annual dosimetry readings, it can be said that the amount of the ionizing radiation varied with the type of the task. These data reveal that technicians are exposed to ionizing radiation in higher doses and longer periods compared to the others. Therefore, a significant difference was observed in their FEV₁ and FEF₂₅₋₇₅ values compared to nurses and doctors.

Maximum mid-expiratory flow (FEF₂₅₋₇₅) value reflects the flow rate of the medium and small airways and this parameter decreases in the early stages of obstructive diseases. Sometimes, the reduction may be seen in restrictive diseases (14). Smoking causes toxic and irritant effect in bronchial epithelium and alveoli, an increase in inflammation, mucus production and ciliary dysfunction (15, 16). Smoking is one of the leading factors that causes chronic obstructive pulmonary disease (COPD). The negative effects of smoking are associated with the number of cigarettes smoked.

Increased smoking is also directly related with increased COPD incidence (15). Significant correlation between FEF_{25-75} value and the beginning time of smoking was shown in the study, as mentioned in the literature.

Cikirikcioglu *et al* showed that asthma attack was triggered by alcohol usage in their study (17). In the pathogenesis of COPD, cigarette smoking, air pollution, lower socio-economic status, occupational exposure, α_1 -antitrypsin deficiency, alcohol abuse, childhood respiratory diseases and genetic predisposition are known to play a role (18–20). Findings in the study showed that there was a significant difference among alcohol use and FVC, FEV_1 and FEF_{25-75} values. Alcohol usage plays a role in the development of obstruction; in normal subjects FVC is equal to vital capacity (VC), however, in the case of obstruction and bronchiolar collapse, FVC is lower than VC. Forced expiratory volume in the 1st second generally reflects the major airways in the same manner, and bronchospasm, inflammation or loss of elastic tissue caused by various factors such as airway obstruction cause a reduction in FEV_1 .

When the relationship between FVC and physical activity was evaluated, Dincer *et al* found vital capacity as 5.12 L for regularly exercising athletes and 4.78 L for sedentary persons (21, 22). In the study by Tasgin and Donmez examining the relationship of exercise on respiratory parameters, PEF and FEF_{25-75} showed significant difference after sports (23).

Mehrotra and colleagues compared pulmonary function tests of athletes engaged in different sports with sedentary persons; the respiratory functions of athletes were higher than those of sedentary persons (24). According to data obtained from the study, about 30% of the staff was engaged in regular sports. It is thought that regular exercise could improve the respiratory function of the radiology staff.

Reduced respiratory function and decreased oxygen carrying capacity may be seen in patients receiving treatment for anaemia (25).

Gundogdu and Eryilmaz, in their study, evaluated PEF values and BMI correlation between obese and non-obese children; they found lower values of PEF for obese compared to non-obese and they observed differences between girls and boys. They mentioned that higher BMI values and lower PEF values in obese children may be the risk factors for lung function decline or reduction of air flow (26). Santana *et al* investigated the relationship between pulmonary functions, anthropometric variables, body composition and physical performance (r) in a study group including 97 males age 67–78 years, with BMI ranging from 19.8–37.1 kg/m². They found that there was a possible correlation between height, body weight, BMI and VC, FVC, FEV_1 and a negative correlation with FEV_1/FVC (27). Gönllügür *et al* (28) retrospectively screened 479 individuals diagnosed with COPD and revealed a positive correlation between BMI and pulmonary function tests; furthermore, weight loss and loss of pulmonary function were more pronounced in males (28). In our study comparing BMI and PEF values according to BMI grouping, FVC,

FEV_1 and PEF values were found to be significantly different and these findings were seen to be parallel with the studies of Gundogdu and Eryilmaz (26) and Gönllügür *et al* (28).

In this study, there was a significantly positive correlation between the functions of the airway dynamic tests FVC, FEV_1 , PEF, FEF_{25-75} and Hgb, Hct, MCV and RDW values. These findings may be due to continuous exposure to ionizing radiation and consequently its effects on sensitive blood cells. Continuous ionizing radiation could cause anaemia in workers in radiology. As a result, it can be said that anaemia together with respiratory complaints may develop in radiology staff chronically exposed to ionizing radiation.

CONCLUSION

Although radiology workers are protected as much as possible, they are exposed to continuous ionizing radiation. Therefore, routine chest X-ray, eye examination, complete blood count and peripheral blood smear were performed in certain periods within this framework. In addition to these routine controls, routine pulmonary function tests should be recommended for higher life expectancy and improved quality of life.

REFERENCES

- Oyar O, Gürsoy UK, eds. Basic concepts of physics in radiology. Ankara: Nobel Book Stores; 1998.
- Oyar O, Gülsoy UK, eds. Medical imaging physics. Ankara: Rekmay Print; 2003.
- Margulis AR, Eisenberg RL. Gastrointestinal radiology from the time of Walter B Cannon to the 21st Century. *Radiology* 1991; **178**: 297–302.
- Saygin M, Çetinkaya G, Yasar S, Kayan M, Yağlı MA, Kurt Y. Eating habits of radiodiagnosics staff. *Smyrna Tip Dergisi* 2011; **1**: 10–15.
- Hall EJ. Radiobiology for radiologist. 3rd edition. Philadelphia: Lippincott Co; 1988: 36–54.
- Ward JF. DNA damage produced by ionizing radiation in mammalian cells: identities, mechanisms of formation, and reparability. *Prog Nucleic Acid Res Mol Biol* 1988; **35**: 95–125.
- Yıldırım H. Biophysics. Eskişehir, Turkey: Anadolu University Press; 1985.
- Özalp A. Basic radiobiology. İstanbul, Turkey: Haliç University Press; 2001.
- Tubiana M, Dutreix J. Introduction to radiobiology. Paris, France: Taylor & Francis, 1990: 24–99.
- Chopp GL. Clinics in chest medicine; pulmonary function testing. Philadelphia, USA: WB Saunders Company; 2001.
- Coggle JE. Biological effects of radiation. London, England: Wykeham Publ; 1977.
- Yasar S, Saygin M, Kayan M, Orhan H. Effects of ionized radiation on quality of life. *Smyrna Tip Dergisi* 2012; **2**: 18–22.
- American Thoracic Society. Lung function testing: selection of reference values and interpretative strategies. *Am Rev Respir Dis* 1991; **144**: 1202–18.
- Hughes JMB, Pride NB. Lung function tests. Physiological principles and clinical applications. London: WB Saunders; 1999.
- Bartal M. COPD and tobacco smoke. *Monaldi Arch Chest Dis* 2005; **63**: 213–25.
- Kömüs N, Tertemiz KC, Sevinç C. Importance and clinical significance of cases who are under risk of COPD (Stage 0). *Tuberk Toraks* 2008; **56**: 382–9.
- Çikirikcioglu YB, Kömürçüoğlu B, Bilaçeroğlu S, Akpınar M, Çelikten E. Serum lipid profile changes in asthma patients during acute attack and stable period. *Toraks Dergisi* 2003; **4**: 7–11.

18. Celli B, Benditt J, Albert RK. Chronic obstructive pulmonary disease. In: Albert R, Spiro S, Jett J, eds. *Comprehensive respiratory medicine*. London: Mosby Harcourt Brace and Company Limited; 1999: 1–24.
19. Çelik G, Erdem F, Alper D. Chronic obstructive pulmonary disease. In: Numanoğlu N, ed. *Clinical respiratory system and diseases*. Ankara: Antip AŞ; 1997: 379–400.
20. Tutluoğlu B. COPD epidemiology. In: Umut S, ed. *Chronic obstructive pulmonary diseases seminar notes*. İstanbul: Küre Press; 1997.
21. Dinçer S, Kaplan B, Hazır M, Gönül B. Differences in vital capacity and some blood parameters between elite athletes and sedentary individuals. *Hacettepe Üniversitesi Spor Bilimleri Dergisi* 1992; **3**: 42–3.
22. Dinçer S, Arslan C, Kaplan B, Ongun Ö, Gönül B. Comparison of some respiratory and haematologic parameters between elite women and men athletes. *Hacettepe Üniversitesi Spor Bilimleri Dergisi* 1993; **4**: 35–6.
23. Taşgin E, Dönmez N. The effect of the exercise program applied to children between 10 and 16 ages on the respiratory parameters. *Selçuk Üniversitesi Beden Eğitimi ve Spor Bilim Dergisi* 2009; **11**: 131–6.
24. Mehrotra PK, Varma N, Tiwari S, Kumar P. Pulmonary functions in Indian sportsmen playing different sports. *Indian J Physiol Pharmacol* 1998; **42**: 412–16.
25. Delisser HM, Grippi MA. Perioperative respiratory considerations in the surgical patient. In: Fishman AP, ed. *Fishman's pulmonary diseases and disorders*. London: McGraw-Hill; 1998.
26. Gundogdu Z, Eryilmaz N. Correlation between peak flow and body mass index in obese and non-obese children in Kocaeli, Turkey. *Prim Care Respir J* 2011; **20**: 403–06.
27. Santana H, Elena Z, Emanuela T, Paolo T, Luisa B, Mario O et al. Relation between body composition, fat distribution, and lung function in elderly men. *Am J Clin Nutr* 2001; **73**: 827–31.
28. Gönlüğür U, Akkurt İ, Efeoğlu T, Çınar Z. Body mass index in COPD cases. *Akciğer Arşivi* 2004; **1**: 35–9.