medicinska revija
medical review

UDK: 612.24
COBISS.SR-ID 22369545

Mulić M. et al ■ MD-Medical Data 2020;12(3) 129-132

*Opšti pregledi/*
*General review*

# LUNG DIFFUSION CAPACITY FOR CARBON MONOXIDE (DLCO), SPIROMETRY VALUES AND ECG ABNORMALITIES IN ELITE ATHLETES: THE LATEST FINDINGS AND LITERATURE REVIEW

# DIFUZIJSKI KAPACITET PLUĆA ZA UGLJEN MONOKSID, SPIROMETRIJSKI PARAMETRI I PROMENE NA EKG-U KOD VRHUNSKIH SPORTISTA: NAJNOVIJA SAZNANJA I PREGLED LITERATURE

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*Abstract:*

The more intensive development of modern sports medicine is related to the period after the Second World War and anthropological, functional, and radiological examinations of athletes as early as the beginning of the 20th century. Performing a DLCO test today is a common diagnostic procedure, immediately after spirometry as a „gold standard" while ECG changes are not yet clearly defined. We have searched Pubmed and Cochrane with Mesh terms: 'DLCO', 'spirometry', 'ECG', 'history', 'mechanism of lung diffusion', 'endurance sports', 'sports medicine'. We searched, in detail, 30 scientific research papers of which 24 were included in the review. **Conclusion**: Through this literature review, we can observe that DLCO test values decrease with age and that there is a strong correlation between body height and DLCO parameters especially in athletes exposed to training under anaerobic conditions. Of particular interest are changes in the ECG that are mainly due to concentric remodeling of the left ventricle and have a significant impact on the prevalence of ECG abnormalities in top athletes.

*Key words*

DLCO, spirometry, ECG, endurance, elite athletes

*Ključne reči*

DLCO, spirometrija, EKG, izdržljivost, vrhunski sportisti

## *INTRODUCTION*

Diffusing capacity of the lung for carbon monoxide (DLCO) also known as a transfer factor for carbon monoxide (TLCO) is metering of conductance or ease of transfer for carbon monoxide (CO) molecules from alveolar gas to the hemoglobin of the red blood cells in the pulmonary circulation. DLCO is useful for assessing parenchymal lung disease when spirometry or lung volume suggests a decrease in vital capacity (VC), residual volume (RV) or decrease in total lung capacity (TLC). Units in which DLCO is expressed are ml/min/mmHg, while mmol/min/kPa are used to express TLCO [1]. According to some authors, DLCO is one of the most valuable and most common tests for assessing lung function. In a healthy population, DLCO is determined by gender, height, and age [2]. On the other side, spirometry is inevitable, equivalent to a gold standard, a test that shows how people inhale or exhale volumes of air as a function of time. By monitoring certain parameters such as forced expiratory volume in the first second (FEV1), forced vital capacity (FVC), Tiffeneau-Pinelli index (FEV1/FVC), maximal voluntary ventilation (MVV), vital capacity (VC), and peak expiratory flow (PEF), it gives us an insight into the lung function both in the general population and in professional athletes who have been shown to have certain deviations [3]. In the general population, some indications for spirometry are lung diseases, especially obstructive disease, then monitoring parameters after some therapeutic interventions, assessment of lung capacity before surgical intervention [4] while the values of DLCO can decrease in some conditions like emphysema, pulmonary fibrosis, or in interstitial lung disease [6,7]. Nowadays, besides the spirometry and DLCO test, some authors found that in the general population with COPD there are changes in the electrocardiogram (ECG) that are significant, so they wanted to check whetherthere are changes in the ECG in elite athletes [8]. Whether and in what physical activity does it have an impact on the human body?

The influence of physical activity is beneficial for the whole body, and the influence of physical activity on lung function is the subject of consideration. According to some research, sports have no effect on lung function while according to others, a correlation between exercise and lung function has been observed [2,5]. In this article, we will discussthe beginnings of sports medicine, the mechanism of DLCO testing, spirometric parameters, and ECG changes in elite athletes.

## *MATERIALS AND METHODS*

We selected relevant studies from the databases of PubMed and Cochrane. The next keywords/ Mesh terms were used: ‘DLCO’, ‘spirometry’, ‘ECG’, elite athletes’, ‘endurance sports’, ‘mechanism lung diffusion’, ‘history’, and ‘sport medicine’. the headline, abstracts, and full-text articles of the possibility of appropriate studies were independently checked by three researches. The reference lists of selected articles were scrutinized for detecting studies which were not grabbed by the electronic search. The study was conducted using literature published up to May 2020. We searched, in detail, 30 scientific research papers of which 24 were included in the review.

**History of sports medicine.** The first records of sports medicine, as a modern discipline, date from the end of the 19th and the beginning of the 20th century and are closely linked to social and cultural changes in the world of medicine, science, and sports [9]. Modern sport can be defined as the application of medicine and science in the study of sports and its implementation in the system of professional associations, scientific conferences, associations of research institutions, and journals [10]. The period after Second World War is associated with the progressive development of modern sports medicine. However, the development of medical equipment dates back to the second half of the 19th century, so the first handled ergometer was built in 1883., and in 1889. the first treadmill and the first bicycle-ergometer were constructed. For the analysis of metabolic changes in the human body under the influence of a defined effort, a gas bag was constructed in 1911 by Scottman Douglas. The first sports medical laboratory was founded in Dresden in 1911. throughout the First International Hygiene Exhibition and included anthropological, functional,and radiological examinations. During the exhibition, all visitors were able to check their physical abilities based on the obtained parameters before and after the exercise, under the control of the doctor [9].

**Mechanism of DLCO**. According to the literature, DLCO presents the product of two measurements through breathe holding at full inflation: the rate constant of carbon monoxide from the alveolar gas (KCO) and „ available“ volume of the alveoli (VA) [11]. It is important to note that KCO is linearly related to the carbon monoxide uptake efficiency by the alveoli where KCO directly maintains the quality of alveo-capillary gas uptake [12]. How is DLCO test performed? The test usually uses the single-breath technique because it is performed faster than all other techniques. In the single-breathe technique, a person exhales to a residual volume (RV) and then inhales a gas test (mostly a tracer gas, consisting of 10% helium or 0,3% methane ) or 21% oxygen, 0,3% carbon monoxide (CO), and equilibrium nitrogen quickly to the total lung capacity (TLC). This vital capacity size breath is retained for 10 seconds and then exhaled into a sample bag or past a sampling port leading to faster response analyzers after an initial discard of 0,75-1l of the exhalate to minimize the share of dead space gas (mouthpiece filter, measuring equipment and anatomical areas where no gas exchange is expected) to the gas sample that will be analyzed to estimate uptake of CO by the alveolar capillaries. The sample (0,75-1l) is then analyzed for tracer gas and CO. The dilution of tracer gas in the vital capacity-size breath of test gas by the patient’s RV ensures both, initial alveolar concentrations for CO and assessment of lung volume at full inflation. The rate of CO diffusion can be evaluated by changing the initial alveolar concentration to that of the sampled expired gradient. This change in concentration of CO is multiplied by the estimated TLC to calculate diffusing capacity which can be affected by some disturbed oxygen levels [1]. In addition to indications for DLCO in the general population, this type of testing is increasingly used in professional athletes. The data obtained by testing differs from study to study. Thus, the researchers in one study compared the parameters obtained by spirometric, DLCO, and KCO tests in athletes, which were divided into those with aerobic (football players) and anaerobic (taekwondo, karate players) training and the control group. At the end of the study analyzing the obtained results, they concluded that there is no difference in the monitored parameters, ie. that the type of training does not affect spirometric parameters or the DLCO values [2]. DLCO values, according to some authors, decline with ages. One study included 33 people from the control group and 29 male athletes engaged in endurance sports, divided into two groups of 20-35 and 65-79 years old. According to their results, DLCO and KCO values were 33% and 25% lower in older and in younger control group. The predicted values for DLCO and KCO in athletes were generally higher by 11% compared to the control group, in older athletes they were 23% and 16% lower then in younger ones. In conclusion, they stated that DLCO in older athletes is lower than in young ones who do not play sports [13]. Among the population of the same age, some researchers have shown that DLCO is higher in athletes then in those who are not. Comparing the general population and top athletes, they provided that there was no statistically significant difference in DLCO and KCO in athletes and control group of the same age. But there is strong correlation between height and DLCO especially in athletes who have undergone anaerobic training [14]. We also found interesting research on monitoring DLCO in combination with chest computed tomography (CT). Namely, thirty years ago researchers examined changes in CT and DLCO in elite male athletes before and after the triathlon. They discovered that there was a significant reduction of DLCO and KCO after the race in the long run, and on CT, an increase in lung density and the appearance of opacity [15].

**Spirometry-introduction to all other tests**. As we mentioned in the introduction, spirometry is the „gold standard " of pulmonary diagnostics in both, the general and sports population. In this topic we will discuss some of the most important spirometric results. One study examined the values of FEV1, FVC, MVV, VC in 493 top athletes in 15 different sport disciplines, comparing these values with 16 non-athletes. The values of VC, FVC, FEV1 were significantly higher in basketball players, water polo players, and rowers compared to the sedentary group. Footballers and volleyball players e.g. had lower VC values and MVV was significantly increased in water polo players and rowers, while in boxers these values were significantly reduced [16]. According to certain research, athletes who play endurance sports such as canoeing, rowing, swimming, marathons, long-distance races, cycling, pentathlon, and triathlon have elevated values of VC, FEV1, and FVC, and the lowest values of FEV1/FVC [17]. Similar data was obtained during other studies, with the proviso that the FEV1/FVC ratio did not change significantly [18]. During their research, most authors, in addition to spirometry, also monitored the anthropometric characteristics of the study participants. Whether there is and what is the connection between anthropometric and spirometric characteristics has been shown by many studies. Some authors believe that all anthropometric characteristics correlate with spirometric parameters. Thus, the highest correlation is achieved between height and weight, especially in endurance sports. Body height has a positive effect on VC, FVC, and FEV1 while body weight has an effect only on FEV1 [17]. Or in one study metering, the total body fat percentage researchers found out that acute exercise resulted in a reduction in fatty acid levels in elite waterpolo athletes [19].

**Changes in the cardiovascular system**. Hypertension is one of the most relevant disorders in elite athletes. Throughout the study they found significantly lower maximal oxygen consumption (VO2 max), ventilatory anaerobic threshold (VAT), and heart rate reserve (HRR) in the groups with high normal blood pressure (HNBP) and hypertension (HT) after adjusting to the type of sport, body fat content and age [20]. In another study, exercise improved the subject's pulmonary function and VO2max, which was improvedthe most by aerobic training [21]. Electrocardiogram (ECG) is a very effective screening tool not just in the cardiovascular area but for example, in chronic obstructive pulmonary disease (COPD) where some researchers saw „Gothic" P wave and verticalisation of the frontal plane axis [22]. The ECG abnormalities in younger athletes have been described in a Japanese study. Irregularities in the ECG were significantly less in the static training group than in the endurance training group. Left ventricle high voltage was observed in as many, as 65% of subjects, mostly men [23]. Some authors recorded that the development of left ventricle concentric remodeling appears to have a significant influence on the prevalence of abnormal ECG, particularly high rate of abnormalities among NBA league athletes [24].

## *CONCLUSION:*

The beginnings of the development of medical equipment have contributed to the further development of sports medicine and to diagnosing certain health problems that can potentially affect athletes. It was shown that there is no statistically significant difference in spirometric and DLCO values comparing aerobic and anaerobic athletes, while others believe that DLCO values decrease with age. Spirometry is an introductory method and also gives important results that are generally consistent in most studies. Changes in ECG have been observed in most athletes but are not clearly defined so this poses a challenge for researchers in the future as well as more intensive monitoring in DLCO values among top athletes.

*Sažetak*

Intenzivan razvoj moderne sportske medicine se vezuje za period posle Drugog svetskog rata, a antropološka, funkcionalna i radiološka ispitivanja kod sportista su počela da se razvijaju početkom 20-og veka. Izvođenje DLCO testa danas predstavlja uobičajenu dijagnostiku, odmah posle spirometrija koja je okarakterisana kao „zlatni standar" dok promene na EKG još uvek nisu jasno definisane. Pretražili smo Pubmed i Cochrane baze podataka sa ključnim rečima: 'DLCO', 'spirometrija', 'EKG', 'istorija', 'mehanizam difuzionog kapaciteta pluća', 'sportovi izdržljivosti', 'sportska medicina'. Do detalja smo pregledali više od 30 naučno-istraživačkih radova od kojih smo 24 uključili u istraživanje. **Zaključak**: Kroz ovaj pregled literature možemo primetiti da se vrednosti DLCO testa smanjuju s godinama i da postoji snažna povezanost između telesne visine i DLCO parametara, posebno kod sportista koji su izloženi treningu u anaerobnim uslovima. Posebno su zanimljive promene na EKG-u koje su uglavnom posledice koncentričnog remodelovanja leve komore i imaju značajan uticaj na prevalencu EKG promena kod vrhunskih sportista.

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■ The paper was received / Rad primljen: 25.09.2020.
Accepted / Rad prihvaćen: 29.09.2020.