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Determining Lung Volume Capacities of Active Bouldering Sport Athletes

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ORIJINAL ARTICLE

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Abstract

This study sought to answer whether lung volume capacities differed by gender in boulder sport climbers. The study was carried out with 12 male and 13 female athletes. Athletes with a training history of more than two years were included in the study. The lung breathing capacities of the boulder sport climbers were measured using the MIR Spirolab 4 spirometer device. The data obtained were analyzed in the SPSS 22.0 package software, and a free seven-day trial version of GraphPad Prism 8 was used for presenting the figures. To determine the normality of the data, the Kolmogorov Smirnov test, the distribution was observed to be normal. Independent samples t-test was used to determine the difference between the two groups. The level of significance was considered as $p<0.05$. The FEV1/FVC, VT, ERV, IRV, IC, MVV, and MVT volume capacities of the boulder sport climbers were similar in male and female athletes. However, VC, PEF, and MEF 75% were significantly different, PEF 25-75% and MEF 50% were highly different, and FEV1 and MEF 25% were at very highly different levels. These differences were in favor of male boulder sport climbers. Contrary to expectations that female athletes had lower lung volume capacities than male athletes, it was determined that while some lung volume capacities of the bouldering athletes were similar in male and female athletes, in other parameters they were in favor of male athletes.

Kewords: Boulder Sport Climbing, Spirometer, Lung Respiration

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Boulder Spor Tırmanışı Yapan Aktif Sporcuların Akciğer Hacim Kapasitelerinin Belirlenmesi

Öz

Bu araştırma, boulder spor tırmanışçılarda akciğer hacim kapasitelerinin cinsiyete göre değişip değişmediğine cevap aradı. Çalışma 12 erkek ve 13 kadın boulder spor tırmanışı yapan sporcu ile sürdürüldü. Çalışmaya en az 2 yıldan daha fazla antrenman geçmişine sahip sporcular dâhil edildi. Boulder spor tırmanışçıların akciğer solunum kapasiteleri MIR Spirolab 4 spirometre cihazı ile ölçüldü. Elde edilen veriler SPSS 22.0 paket programda analiz edildi ve şekilsel ifadeler için yedi günlük ücretsiz GraphPad Prism 8 deneme sürümü kullanıldı. Verilerin normalliğini belirlemek için; Kolmogorov Smirnov bakıldı ve dağılım normaldi. İki grup arasındaki farklılığın belirlenmesi için Independent Samples t testi kullanıldı. Anlamlılık düzeyi $p<0.05$ olarak kabul edildi. Boulder spor tırmanışçı sporcuların FEV1/FVC, VT, ERV, IRV, IC, MVV, MVT hacim kapasiteleri erkek ve kadın sporcularda benzer düzeydeydi. Ancak VC, PEF, MEF %75 anlamlı düzeyde, PEF%25-75, MEF%50 yüksek düzeyde, FEV1 ve MEF%25 ise çok yüksek düzeyde farklıydı. Bu farklılık erkek boulder spor tırmanışçı sporcuların lehineydi. Kadın sporcuların akciğer hacim kapasiteleri erkek sporculara göre daha düşüktür şeklindeki beklentinin aksine, boulder spor tırmanışçılar sporcuların bazı akciğer hacim kapasiteleri erkek ve kadın sporcularda benzer düzeydeyken bazı parametrelerde erkek sporcuların lehine olduğu görüldü.

Keywords: Boulder Spor Tırmanış, Spirometre, Akciğer Solunum

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Introduction

The lungs are the basic organs of the respiratory system, and they are tasked with facilitating the exchange of gas from the environment to the bloodstream. Oxygen is transported from the alveoli to the capillary network, where it enters the arterial system and eventually perfuses the tissue. The respiratory system consists mainly of the nose, oropharynx, larynx, windpipe, bronchi, bronchioles, and lungs. The lungs are also divided into individual lobes, which are ultimately divided into more than 300 million alveoli. Alveoli are the primary location of gas exchange (Haddad and Sharma, 2021). In this context, we think that the amount of oxygen transferred to the blood in gas exchange is important and affects individual performance.

Many parameters affect the performance of athletes. One of these parameters is lung volume capacities. Changes in the lung capacity, especially in inspiration and expiration, can directly affect the performance of athletes. Emphasized that increases occurred in the amount of oxygen input in the body based on increased inspiration, which positively affected the energy transformation in the body (Pine and Watsford, 2005). Based on this effect, the next step is the thought that there is also an increase in the amount of oxygen reaching the muscles during exercise (Şerifoğlu et al., 2021).

Human beings have established evaluation branches such as VT, VC, IRV, ERV, IC, and RV to determine lung volume and capacity levels. In this context, the normal and calm breathing volume is expressed as tidal volume (VT), the volume taken during additional forced inspiration besides tidal volume is called inspiratory reserve volume (IRV), the volume given when a forced expiration is performed after tidal volume is expiratory reserve volume (ERV), and the volume remaining in the lung after forced expiration is named as residual volume (RV). In addition to lung volumes, there is also lung capacity, which includes at least two lung volumes. The capacity consisting of tidal volume and inspiratory reserve volume is accepted as inspiratory capacity (IC) and the total of inspiratory capacity and expiratory reserve volume is evaluated as vital capacity (VC) (Wanger et al, 2005; Hopkins and Sharma, 2022).

When the literature is examined, it is often possible to see statements that lung volume capacities can vary according to height, age, ethnicity, body composition, and level of physical activity. It was stated that gender in particular is one of the critical variables affecting lung capacity ranges (Lofrese et al, 2021; Delgado and Bajaj, 2021). In this respect, it was emphasized in previous studies that men had significantly higher lung volume compared to women of the same height and age. It was stated that this situation was caused by structural differences between men and women, and this argument was put forward on the basis that the female rib cage is smaller than that of the male, the female ribs are at a different angle, and the female diaphragm is shorter (Bellemare et al, 2003). Recently, it was stated that these gender differences in respiratory morphology affect breathing, blood-gas homeostasis, and cardiovascular function and might change the integrative response to exercise (Dominelli et al., 2019).

One of the parameters that determine adaptive changes in respiratory function is exercise. In this regard, it has been stated that physical activity can improve lung function (Kubesch et al., 2015). However, it is not yet possible to access studies regarding the varieties in terms of lung capacities and gender differences of bouldering athletes who try to master short climbs on artificial climbing walls, which are usually less than four to five meters, but these climbs are still challenging at different difficulty levels made without ropes and harnesses, where safety mats are placed on the ground to protect athletes from serious injuries (Schwarz et al, 2019).

Therefore, this study looks for answers to the problematic process of whether the lung respiratory volume capacities of bouldering are completely different by gender, or if there is only a difference in some parameters.

Method

The study is observational in terms of the data collection technique, descriptive according to the causality relationship, and cross-sectional considering the timing relationship. Cross-sectional studies are carried out in the form of an examination of events or facts at some point in time.

Study Group

The study was conducted with 12 male and 13 female bouldering sports athletes during the boulder sports climbing Turkey championship. Athletes with a training history of more than two years were included in the study by pre-evaluating their training histories and their physical characteristics to participate in the study. Athletes who smoked, used alcohol, had lung and heart disease, or had respiratory infections were excluded when determining the research group. Next, demographic information about the athletes such as age and gender were recorded, and their height, weight, and BMI (body mass index) levels were assessed to form a homogeneous group. Athletes with physically similar characteristics were accepted for the research. The athletes were informed about the measurement procedure, and a voluntary consent form was obtained.

Height and Body Weight Measurement

The weights of the participants were identified without shoes using a JASPER Techfit Tf digital glass scale with a precision of up to 20 g. Height measurements were made with the Holtain brand height stadiometer with a sliding caliper while standing in an upright position.

Body Composition and BMI Determination

The body composition of the boulder sport climbers who participated in the study was determined with the Tanita Bc 545 N Innerscan Segmental device. During the measurement, data were obtained by keeping the athletes' hands and feet motionless in contact with the measuring points.

Lung Volume and Capacity Measurement

The device MIR Spirolab 4 spirometer was used to measure the lung volume and capacities of vital capacity (VC), tidal volume (VT), inspiratory reserve volume (IRV), expiratory reserve volume (ERV), inspiratory capacity (IC), forced expiratory volume (FEV1), forced expiratory ratio (FEV1/FVC), peak expiratory flow rate (PEFR), maximal mid-expiratory flow rate (PEF 25-75%), maximal expiratory flow rate percentage (MEF 25-75%), tidal volume during maximal voluntary ventilation (MVt) and maximal voluntary ventilation (MVV). Measurements were made on each athlete at least three times, and their best value was recorded. The measurement parameters were in line with the criteria set by the American Thoracic Society (ATS)/European Respiratory Society (ERS). During spirometry measurements, athletes were seated and dressed in comfortable clothing, and spring nose clips were attached to the athletes' noses to prevent air leakage. At the time of measurement, the air temperature was in the range of 18-22 °C, and humidity was 30-60%.

Analysis of Data

The data obtained were analyzed in the SPSS 22.0 package program and a free seven-day trial version of GraphPad Prism 8. To determine the normality of the data, the Kolmogorov Smirnov test, histogram charts, skewness and kurtosis, q-q plot, and stem and leaf plots were evaluated, and the distribution was found to be normal. Independent samples t-test was applied for group comparisons. The level of significance was set as $p<0.05$ in all tests.

Findings

The findings of the research are given in tables below and interpreted.

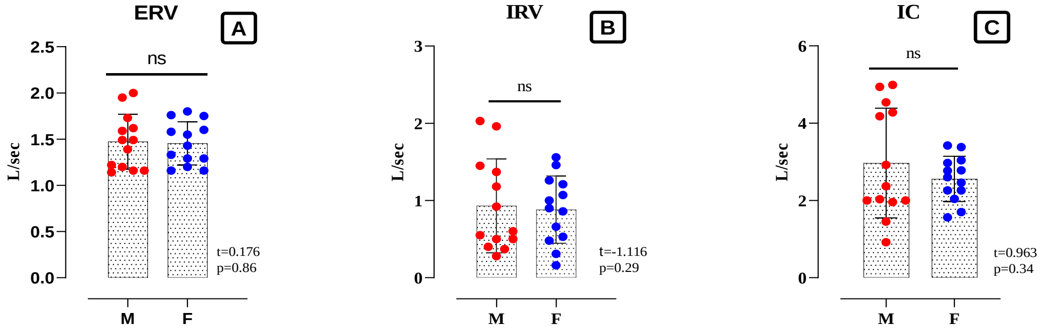
Table 1

The gender, age, height, weight, and BMI distributions of boulder sport climbers

Characteristics	Male	Female
Gender	12	13
Age	14.5±1.88	14.3±1.93
Height (cm)	163.8±9.01	159.8±8.31
Weight (kg)	49.1±11.21	48.7±10.35
BMI	16.7±1.63	16.5±1.98

According to Table 1, 12 boys and 13 girls participated in the study. The mean age of the boys and girls in the study was close to each other. In addition, boys had a height of 163 cm and girls had a height of 159 cm. When we look at the whole body weight, the average of the boys was 49 kg and the girls were 48 kg. BMI values were close to each other and the average was 16.

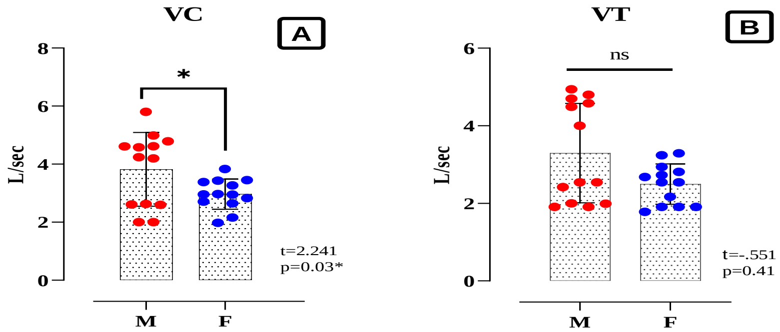
Figure 1
The ERV, IRV, and IC results of the boulder sport climbers



p>0.05, ns: not significant, M: Male, F: Female, t: Independent samples t-test, ERV: Expiratory reserve volume, IRV: Inspiratory reserve volume, IC: Inspiratory volume capacity. The colored circles signify the clustering of participants around the arithmetic average.

According to Figure 1, there was no significant difference between ERV (Figure 1A), IRV (Figure 1B), and IC (Figure 1C) volume capacities in male and female boulder sport climbers (p>0.05).

Figure 2
The VC and VT results of the boulder sport climbers

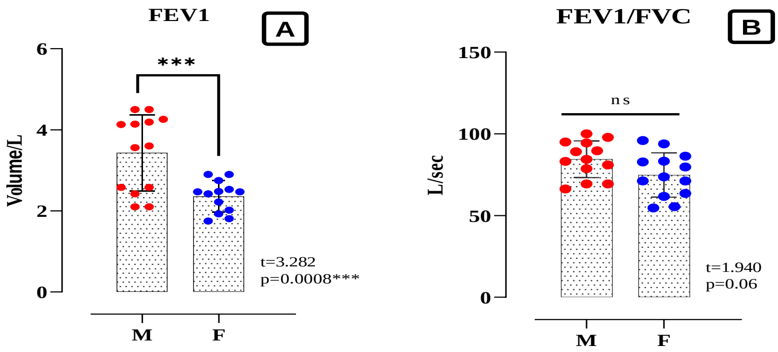


*: p<0.05, ns: not significant, M: Male, F: Female, t: Independent samples t-test, VC: vital capacity, VT: tidal volume. The colored circles signify the clustering of participants around the arithmetic average.

According to Figure 2, there was a significant difference between the VC (Figure 2A) capacities of male and female boulder sport climbers (p<0.05). This difference was in favor of maleouldering climbers. However, there was no significant difference between the VT capacities of the athletes in the study (p>0.05).

Figure 3

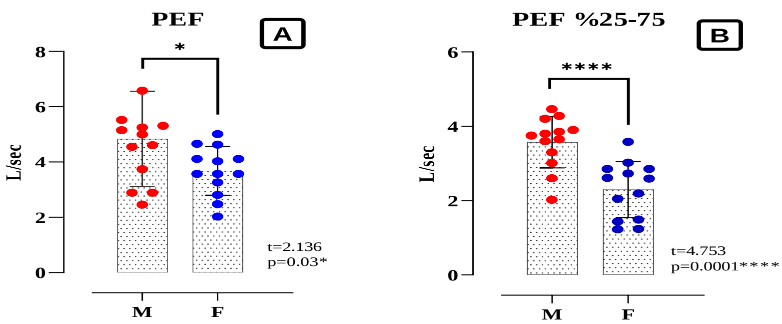
The FEV1 and FEV1/FVC results of the boulder sport climbers



***: p<0.001, ns: not significant, M: Male, F: Female, t: Independent samples t-test, FEV1: Forced expiratory volume, FEV1/FVC: Forced expiratory volume-Forced vital capacity. The colored circles signify the clustering of participants around the arithmetic average.

According to Figure 3, there was a very high degree of statistically significant difference between the FEV1 (Figure 3A) capacities of male and female boulder sport climbers (p<0.001). This difference was in favor of male boulder climbers. That is, the male bouldering climbers had a higher level of forced expiratory volume capacity than female climbers. However, when the FEV1/FVC capacities of the male and female climbers in the study are examined, it was found that the air exhaled in the first second of a forced expiration did not change according to the gender variable, and there as no significant difference (p>0.05, Figure 3B), even though the average scores of male boulder sport climbers were found to be slightly higher than those of the female athletes.

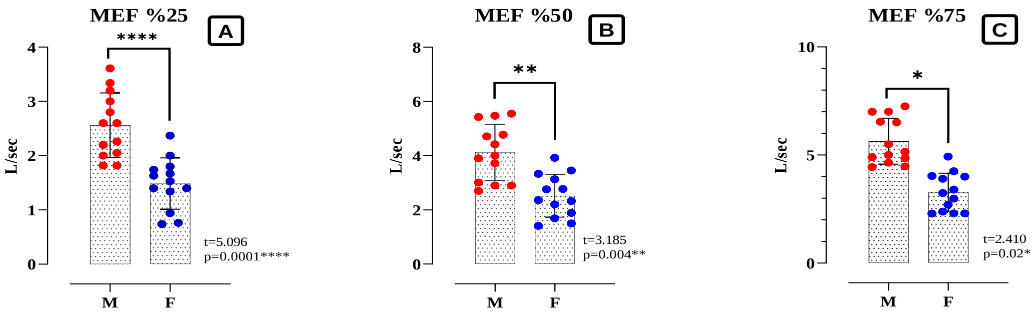
Figure 4
The PEF and PEF 25-75% results of the boulder sport climbers



*: p<0.05, ****: p<0.001, M; Male, F; Female, t: Independent samples t-test, PEF: Peak expiratory flow rate, PEF %25-75: Maximal mid-expiratory flow rate. The colored circles signify the clustering of participants around the arithmetic average.

As demonstrated in Figure 4, there was a statistically significant difference between the PEF (Figure 4A) flow rates of male and female boulder sport climbers (p<0.05). The difference was in favor of male boulder climbers. In other words, male bouldering athletes had a higher peak expiratory flow rate than female climbers. Another difference in the study was in the PEF 25-75% flow rates of male and female climbers, and this difference was at a very high level (p<0.001, Figure 4B).

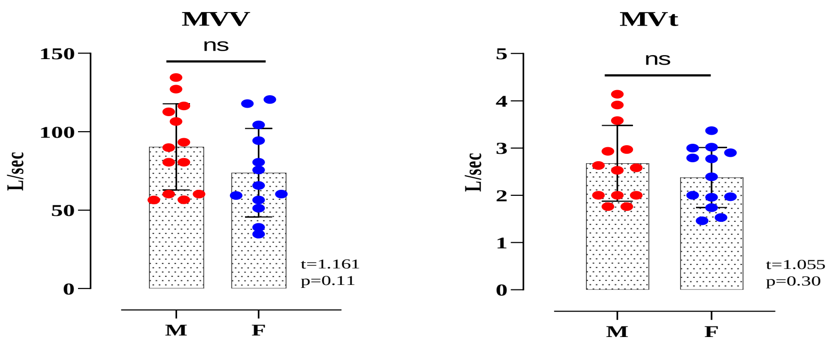
Figure 5
The MEF 25%, MEF 50%, and MEF 75% Results of the Boulder Sport Climbers



*: p<0.05, **: p<0.01 ****; p<0.001, M: Male, F: Female, t: Independent samples t-test, MEF %25-75: Maximum expiratory flow rate percentage. The colored circles signify the clustering of participants around the arithmetic average.

As seen in Figure 5, there was a very high degree of significant difference between the MEF 25% (Figure 5A) flow rate of male and female boulder sport climbers (p<0.001). The difference was in favor of male boulder sports climbers. That is, male bouldering athletes had a higher level of maximum expiratory flow mid-rate percentage than female climbers. Another difference in the study was between the MEF 50% flow rate of the male and female climbers, and this difference was (p<0.01, Figure 5B). In addition, the MEF 75% flow rate between the males and females was statistically significant (p<0.05).

Figure 6
The MVV and MVt results of the boulder sport climbers



p>0.05, ns: not significant, M: Male, F: Female, t: Independent samples t-test, MVV: Maximal voluntary ventilation, MVt: tidal volume during maximal voluntary ventilation. The colored circles signify the clustering of participants around the arithmetic average.

According to Figure 6, there was no significant difference in the gender variable in terms of the MVV (Figure 6A) and MVT (Figure 6B) maximal voluntary ventilation volumes between the male and female boulder sport climbers (p>0.05).

Discussion

Today, the reliability dimension of the assessments made with the updated spirometer measurements is determined by the "American Thoracic Society/European Respiratory Society."

These communities state that spirometer measurements are carried out in sporting evaluations as in other areas in the world. Spirometer measurements made based on sporting evaluations can vary according to the athlete's height, age, body composition, athlete's mobility, physical activity level, sports branch, and the environment of the athlete (such as high altitude, humidity, and temperature), and gender may be one of the important variables affecting the lung respiratory capacity volume ranges in particular (Delgado and Bajaj, 2021). This is because it has been reported that significant improvements occur in the perception and executive physiological function of children and young people with high levels of physical activity (Hillman et al, 2008), and brain blood flow rate increases due to increased capillary (angiogenesis) intensity in athletes in different branches who do endurance exercises (Adkins et al, 2006). These two judgments are based on the critical ability of alveolarization, which increases alveolar surface area and pulmonary capillary blood volume, with an emphasis on the capacity level related to respiratory function ability (Chang et al, 2014). In this framework, it is known that alveoli are in the primary step during the gas exchange phase; oxygen from alveoli is transported to the capillary network; it enters the arterial system through the capillary network; it arrives at the tissue and perfuses the region it reaches in this system (Lutfi, 2017; Lofrese et al, 2021). Therefore, the measurement of lung volumes and capacities is important for detecting respiratory function ability (Zimmermann et al, 2019). In this respect, the literature showed us that the determination and output presentations in lung volumes and capacities under the title of sports branches were not sufficient. The addition of scarcity in information about the lung respiratory volume capacities of boulder climbing sports athletes led us to conduct a gender-based detection study.

When expressing the physiological process of ERV, it is emphasized that the chest and abdominal expiration muscles contract and rise above the intrapleural pressure (Ppl) and alveolar pressure (Palv) above the atmospheric pressure, and the pressure inside the alveoli becomes higher than that of the pleura due to the elastic repulsion of the alveoli, and ultimately the alveoli remain open (Lofrese et al, 2021). In this context, there was no significant difference between ERV volume capacity levels of male and female boulder sport climbers in the study (Figure 1A). Therefore, the volume of gas emitted with a forced expiration after the normal tidal volume was given showed similar characteristics in male and female athletes. In other words, we think that the alveolar pressure level and the ability of alveoli to stay open are at a similar level among male and female boulder sport climbers. A divided 36 women who were not athletes but had similar BMI (body mass index), full body weight, and age into three groups (aerobic, resistance, and interval exercise) and applied exercise for eight weeks (Moradians et al, 2016). They reported that these exercises did not affect the pre/post-test ERV volume capacities of the female participants.

No significant difference was found between the IRV volume capacity levels of male and female boulder sport climbers (Figure 1B). Therefore, we can state that the volume capacity that can be inhaled after a normal inspiration will not change depending on gender and physical activity. In the literature, it was found that access to spirometry IRV measurement findings was rather limited. Aygün stated that eight weeks of respiratory muscle training in Karate Kumite athletes did not affect IRV (Aygün, 2016). Koç performed breathing muscle exercises and breathing exercises for 30 min/3 days/8 weeks on 32 taekwondo athletes (experimental: 15, control: 17) who had been doing sports for at least one year but reported that IRV values did not differ between the experimental and control groups (Koç, 2017).

Although male athletes had a higher IC scoring average in terms of IC volume capacity levels, there was no significant difference between male and female boulder sport climbers (Figure 1C). Moradians et al (2016) reported a significant increase in non-athlete women due to eight weeks of interval training in IC, which consists of tidal volume and inspiratory reserve volume. The fact that this study was conducted only with female subjects and the insufficient arguments on IC revealed by the literature on IC capacities require further studies to be carried out on this subject.

In the present study, a significant difference was found in the VC volume capacity levels of male and female boulder sport climbers (Figure 2A). The difference was that male boulder athletes scored higher averages of VC volume capacity than female athletes. VC, which is described as the sum of deep air exhaled after a deep breath inhalation, is expressed as the inspiratory reserve volume, tidal volume, and expiratory reserve volume (Guyton and Hall, 2020). Another precursor to this significant difference in VC volumes in male boulder sport climber athletes compared to females in this study was that the average scores of ERV, IRV, and VT volumes were in favor of male athletes. Melekoğlu et al (2018) stated that if 13–14-year-old adolescents with similar physical characteristics participate in out-of-school physical education activities (at least five years of licensed athletes; athletics, football, handball, and swimming) besides the physical education classes at school, these extra activities will make important contributions to respiratory health and system. Therefore, we think that planned and structured exercise and qualified mobility skills will have a positive effect on VC volume capacity by drawing upon the fact that sports branches improve lung breathing and capacity volumes.

When the FEV1 volume capacity levels of male and female boulder sports climbers were examined in the study, a very high significant difference was detected (Figure 3A). This difference demonstrated that males have a higher level of forced expiratory volume capacity than female boulder sport climbers, and the air volume male athletes produced in the first second was higher than that of female athletes. On the other hand, there was no significant difference in FEV1/FVC volume capacities. Vignesh et al (2018) stated that the FEV1 volume capacity of individuals who exercise regularly is higher than that of individuals who do not, and regular exercises have a great effect on lung function, while Saputri et al (2018) reported that the FEV1/FVC ratio will be better in individuals who do sports (13-15 years) than those who do not exercise. Minaeifar et al (2020) maintained that the FEV1 volume capacities of factory employees who did sports were higher than those who did not in their study carried out with 74 roof tile factory employees. By making spirometry measurements of male and female boulder athletes in different branches with an average age of 23 at the 20th National Indonesian Olympic Games, Azam et al (2021) determined that the FEV1 volume capacities differed significantly between male and female athletes, and male athletes had higher FEV1 than females, whereas FEV1/FVC did not differ.

In this study, a statistically significant difference was found between the PEF (Figure 4A) flow rate of male and female boulder sports climbers ($p<0.05$). Accordingly, males had a higher peak expiratory flow rate than female boulder sports climbers. Another finding in the study was that the difference in PEF 25-75% flow rate of male and female climbers was highly significant ($p<0.001$, Figure 4B). Azam et al (2021) stated that there was no significant difference in male and female boulder athletes in different branches, but men had more average points than women. In addition, the expression that 'the athlete's branch affects the PEF flow rate' is noteworthy. In this respect, it was stated that the athletes in the weightlifting branch had the lowest PEF flow rate while the target sports athletes (such as shooting and archery) had the highest rate, and there was no significant difference in other branches (such as boxing, taekwondo, ball games, wheeled sports and sports done with an instrument).

In this study, the MEF 25% (Figure 5A) flow rate of male and female boulder sports climbers was significantly different at a very high degree ($p<0.001$), MEF 50% flow rate was significantly different at a high level ($p<0.01$, Figure 5B), and MEF 75% flow rate was significantly different ($p<0.05$). Therefore, it can be said that male boulder sport climbers have a higher level of maximum mid-expiratory flow rate than female climbers. Tartibian and Khayat (2018) stated that eight weeks of high-intensity interval training (HIIT) and resistance exercises in sedentary men significantly increased the MEF 25-75% flow rate compared to the control group, and these two exercise applications would reduce the risk of asthma and other respiratory disorders. Wu et al (2020) reported that regular aerobic exercises will significantly increase the MEF 25-75% flow rate and therefore improve the quality of life, especially in asthma patients.

In this research, MVV (Figure 6A) and MVT (Figure 6B) maximal voluntary ventilation volumes were similar between the sexes in male and female boulder sports climbers ($p>0.05$). Mazic et al (2015) stated that MVV values in athletes are substantially high compared to sedentary individuals. Melekoğlu et al (2018) reported that the MVV volumes of individuals participating in physical activity were higher than those who did not participate. Hence, we think that exercise has a significant effect on MVV and MVT volumes.

Conclusions

When we look at the lung volume capacities and measurements made with the spirometer, it is possible to find widespread judgments in the literature stating that exercise improves these capacities. Even in the treatment of chronic diseases such as COPD, the emphasis that exercise can be an important prescription is remarkable. However, it was observed that in most studies variables such as age, race, BMI, height, and weight were frequently processed, while gender was handled over one sex. This research sought answers to the research question of whether the lung respiratory volume capacities of boulder sport climber athletes are completely different by gender, or if there is a difference only in some parameters, and the results of the study provided the answer that there are differences in some parameters (VC, FEV1, PEF, PEF25-75, and MEF25-75). Therefore, even if a background in sports is an important stimulus in improving lung volume ability, we found that not all volume capacities were affected when viewed from the perspective of gender. We can also state that the affected capacity levels are of different extents, and the lung respiratory volume ability is in favor of male athletes.

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