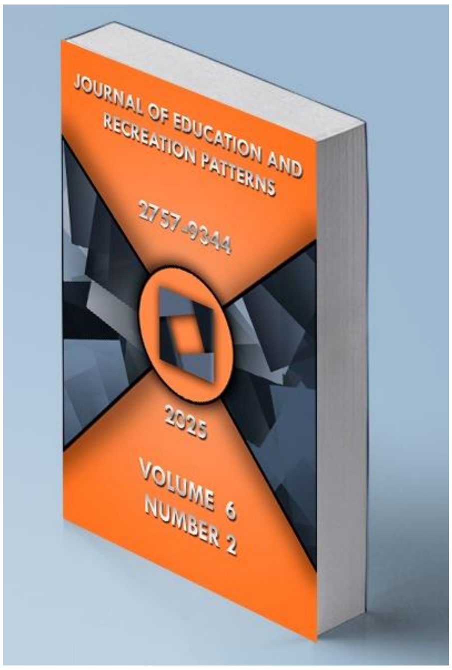

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Effects of Cross-Country Skiing and Volleyball Training Characteristics on Some Respiratory Parameters in Female Athletes*

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ABSTRACT

This study aimed to examine the effects of sport-specific training on selected respiratory parameters in female cross-country skiers and volleyball players. A total of 36 women voluntarily participated in the study, including 12 cross-country skiers (age: 19.17 ± 1.11 years), 12 volleyball players (age: 20.42 ± 2.19 years), and 12 sedentary controls (age: 20.42 ± 2.27 years). Pulmonary function values were measured using a spirometer under standardized conditions. Statistical analyses were conducted using SPSS v30. Since the data showed a normal distribution, a one-way ANOVA was applied to compare mean respiratory parameters among groups, followed by Tukey's post-hoc test for pairwise comparisons.

The results indicated that forced expiratory volume in one second (FEV_1), the FEV_1/forced vital capacity ratio (FEV_1/FVC), peak expiratory flow rate (PEF), forced expiratory flow between 25-75% of vital capacity (FEF_{25-75}%), and maximal voluntary ventilation (MVV) were significantly higher in cross-country skiers than in sedentary participants ($p < 0.05$). Moreover, cross-country skiers demonstrated significantly higher FEV_1/FVC and FEF_{25-75}% values compared to volleyball players ($p < 0.05$). Volleyball players exhibited significantly higher PEF and MVV values than sedentary participants ($p < 0.05$), while no significant differences were found in the remaining parameters ($p > 0.05$).

In conclusion, female cross-country skiers displayed superior respiratory function compared with volleyball players and sedentary women. These findings suggest that the physiological demands and training characteristics of cross-country skiing may contribute more effectively to the enhancement of respiratory capacity.

Keywords: Cross-Country Skiing, Exercise Physiology, Respiratory Function, Sedentary Women, Volleyball.

* This study was presented as an oral presentation at the 22nd International Sports Science Congress, hosted by Gazi University in Ankara between November 21-24, 2024.

INTRODUCTION

Designing training programs that enhance the physical, physiological, and motor performance of female athletes represents a key focus in contemporary sports science research. The specific training characteristics required by different sport disciplines can induce distinct respiratory system adaptations, thereby influencing athletic performance and health (McArdle et al., 2010). Adaptations within the respiratory system are critical determinants of both exercise performance and overall well-being (Wilmore & Costill, 2004). Parameters such as maximal oxygen uptake (VO_2max), ventilatory thresholds, and pulmonary function indices are commonly used to assess athletes' physiological responses to varying training loads (Saltin & Åstrand, 1967). Understanding how physiological and hormonal differences influence respiratory adaptations in female athletes is essential not only for optimizing performance but also for safeguarding health and promoting long-term participation in sport. Although lung function is influenced by factors such as body composition, stature, sex, age, ethnicity, and genetics, evidence suggests that physically active individuals generally exhibit superior respiratory function compared with sedentary peers (Fox et al., 1993; Atan et al., 2012). Regular and long-term exercise induces numerous systemic adaptations and contributes to the development of respiratory function (Patlar et al., 2000).

The extent to which training influences pulmonary function appears to depend largely on the structural characteristics and intensity of the training stimulus. Respiratory muscle strength, in particular, plays an important role in the efficiency of breathing and overall ventilatory capacity. Given the contribution of respiratory and core musculature to ventilatory mechanics, their development level is a crucial determinant of athletic performance (Shin et al., 2017). A well-developed lung capacity is vital for meeting oxygen demands during exercise and ensuring effective oxygen transport to working tissues, as it represents a primary component of cardiorespiratory fitness (Caspersen et al., 1985). Metabolic adaptations are known to vary with exercise type, duration, and intensity, and different training modalities may elicit distinct changes in respiratory frequency and volume (Losnegard & Hallén, 2014). Because each sport imposes unique physiological demands, the nature of the training stimulus determines the extent and specificity of respiratory adaptations. While cardiovascular function is a well-established determinant of endurance performance, enhanced pulmonary capacity directly supports endurance by facilitating more efficient oxygen uptake and utilization.

Cross-country skiing is a sport characterized by high respiratory system activation and requires a complex interplay of balance, strength, speed, agility, and particularly endurance capacity. Given the demanding nature of its training structure, cross-country skiing imposes substantial stress on both the cardiovascular and respiratory systems while simultaneously engaging nearly all major muscle groups, thereby promoting technical and physiological adaptations (Sandbakk & Holmberg, 2014). In contrast, volleyball training-although less dependent on continuous endurance-plays a crucial role in improving respiratory efficiency and lung capacity through intermittent high-intensity actions and frequent upper-body involvement (Bilici & Genç, 2020). Cross-country skiing and volleyball therefore differ markedly in their energy system utilization, muscular activation patterns, and physical demands. Whereas cross-country skiing primarily emphasizes aerobic endurance and sustained oxygen delivery, volleyball performance relies more on anaerobic power output, rapid recovery, and explosive movements within team-based dynamics (Brooks et al., 2005). These physiological distinctions may lead to sport-specific adaptations in respiratory parameters.

Although the beneficial effects of regular exercise on pulmonary function have been well documented, comparative research exploring how distinct training modalities influence respiratory adaptations in female athletes remains limited. Accordingly, evaluating and contrasting the respiratory responses of athletes engaged in sports with divergent physiological and technical characteristics-such as cross-country skiing and volleyball-provides valuable insight for optimizing training design and safeguarding respiratory health. Therefore, the present study aimed to investigate the effects of sport-specific training in cross-country skiing and volleyball on selected respiratory parameters in female athletes.

METHOD

Participants

This Thirty-six women voluntarily participated in this study (Table 1). The sample included 12 cross-country skiers, 12 volleyball players, and 12 sedentary women who met the inclusion criteria of being nonsmokers, free from chronic disease, and having experienced no acute health issues within the preceding three weeks. The athlete groups consisted of individuals with a minimum of three years of systematic training experience, engaging in regular practice at least five days per week for more than one hour per session.

All participants were informed in detail about the study's objectives, procedures, and potential risks, and each provided written informed consent in accordance with the Declaration of Helsinki. Participants were instructed to avoid strenuous physical activity, caffeine consumption, or any behavior that might influence respiratory measurements within 24 hours before testing.

Study Design

This study employed a cross-sectional, comparative design aimed at examining differences in selected respiratory parameters among female cross-country skiers, volleyball players, and sedentary controls. All measurements were conducted under standardized laboratory conditions. Participants were fully informed about the study objectives, procedures, and potential risks, and each provided written informed consent prior to participation. To ensure participant familiarity with the spirometry procedures and to minimize measurement variability, athletes performed a practice trial before formal testing. The research protocol was reviewed and approved by the Muş Alparslan University Scientific Research and Publication Ethics Committee (Date and No: 27.12.2024 - 175292). All procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

Data Collection Tools

Anthropometric Assessments: Body height, body weight, and body mass index (BMI) were recorded for all participants. Height was measured to the nearest 0.1 cm using a stadiometer while participants stood barefoot and upright. Body weight was determined using a Tanita BC-730 Body Composition Analyzer (Tokyo, Japan) with participants wearing lightweight clothing (t-shirts and sweatpants). Body mass index was calculated using the standard formula (BMI = weight [kg] / height² [m²]).

Respiratory Measurements: Pulmonary function was assessed using a Pony FX spirometer (Cosmed, Rome, Italy) to determine functional lung volume and capacity parameters in accordance with established guidelines (Atan et al., 2012; Durmic et al., 2015). Participants were instructed to abstain from smoking, alcohol or caffeine intake, medication use, and strenuous exercise for 24 hours before testing.

All measurements were performed in a seated position, with the nose occluded by a nasal clip and the mouth sealed around the spirometer mouthpiece. After several normal breathing cycles, participants were asked to inhale maximally and then exhale forcefully and completely. Each test was repeated twice, and the highest value was recorded for analysis. The following parameters were examined: Forced Vital Capacity (FVC), Forced Expiratory Volume in One Second (FEV_1), FEV_1/FVC ratio, Peak Expiratory Flow (PEF), Forced Expiratory Flow at 25-

75% of vital capacity (FEF_{25-75}%), Vital Capacity (VC), and Maximal Voluntary Ventilation (MVV).

Data Analysis

All data were organized and visualized using Microsoft Excel, while statistical analyses were performed with IBM SPSS Statistics version 30.0 (Armonk, NY, USA). The Shapiro–Wilk test was used to verify the normality of the data distribution. Since the data were normally distributed, a one-way analysis of variance (ANOVA) was applied to compare respiratory parameters among groups. Tukey's post hoc test was employed for pairwise comparisons where significant differences were detected. Additionally, Pearson correlation analysis was used to examine associations between selected variables. Statistical significance was set at $p < 0.05$.

FINDINGS

The analysis focused on evaluating differences in respiratory function parameters among female cross-country skiers, volleyball players, and sedentary participants. Descriptive statistics were calculated for all variables, and one-way ANOVA was conducted to determine intergroup differences. The overall findings revealed that sport-specific training had a marked influence on several pulmonary function parameters. Athletes, particularly those engaged in cross-country skiing, exhibited superior respiratory performance compared with sedentary women, indicating clear sport-related physiological adaptations in ventilatory capacity and expiratory function.

Table 1

Descriptive Characteristics of the Study Participants (Mean ± SD).

Groups	N	Age (years)	Body Weight (kg)	Height (cm)	BMI (kg/m2)
Cross-Country	12	19.17±1.11	54.08±3.94	164.75±3.93	19.85±0.96
Volleyball	12	20.42±2.19	55.58±6.50	163.75±5.85	20.71±1.76
Sedanter	12	20.42±2.27	52.67±8.06	162.67±5.09	19.89±2.77

BMI = Body Mass Index

Table 2

Comparison of Respiratory Parameters Among Female Cross-Country Skiers, Volleyball Players, and Sedentary Participants

Parameters	Groups	N	Average.	SD.	F	p	Tukey
FVC(L)	A- Cross-Country	12	3.77	0.24	1.65	.207	
	B-Volleyball	12	3.78	0.11			
	C-Sedanter	12	3.39	0.13			
FEV1(L)	A- Cross-Country	12	3.47	0.18	4.76	.015*	A>C
	B-Volleyball	12	3.21	0.11			
	C-Sedanter	12	2.87	0.11			
FEV1/FVC% (%)	A- Cross-Country	12	92.8	1.38	8.55	.001*	A>B A>C
	B-Volleyball	12	85.3	1.22			
	C-Sedanter	12	85	1.86			
PEF (L/s)	A- Cross-Country	12	6.12	0.4	12.45	.000*	A>C B>C
	B-Volleyball	12	5.67	0.3			

	C-Sedanter	12	3.93	0.27			
FEF25-75% (L/s)	A- Cross-Country	12	4.37	0.21	10.39	.000*	A>B A>C
	B-Volleyball	12	3.63	0.23			
	C-Sedanter	12	3.11	0.15			
VC (L)	A- Cross-Country	12	3.6	0.24	1.12	.337	
	B-Volleyball	12	3.47	0.12			
	C-Sedanter	12	3.25	0.11			
MVV (L/min)	A- Cross-Country	12	97.1	7	4.23	.023*	A>C B>C
	B-Volleyball	12	97.86	5.79			
	C-Sedanterler	12	77.48	3.49			

FVC - Forced Vital Capacity; FEV_1 - Forced Expiratory Volume in One Second; FEV_1/FVC - Ratio of Forced Expiratory Volume to Forced Vital Capacity; PEF - Peak Expiratory Flow; $FEF_{25-75}\%$ - Forced Expiratory Flow between 25-75% of Vital Capacity; VC - Vital Capacity; MVV - Maximal Voluntary Ventilation.
Note: $p < 0.05$ indicates statistical significance (Tukey post hoc test).

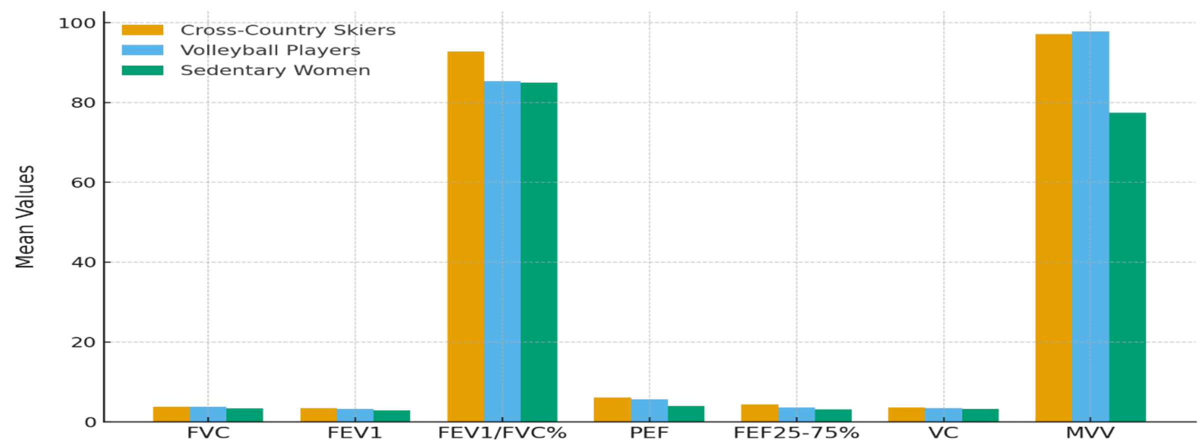
Table 2 presents the results of the one-way ANOVA comparing the respiratory parameters of female cross-country skiers, volleyball players, and sedentary participants. Overall, the findings indicate that regular sport-specific training produces significant improvements in several pulmonary function indicators compared to a sedentary lifestyle. Among the measured parameters, FEV_1, FEV_1/FVC, PEF, $FEF_{25-75}\%$, and MVV showed statistically significant differences between groups ($p < 0.05$), highlighting the superior ventilatory performance of the athlete groups.

The cross-country skiers demonstrated the highest mean values across nearly all parameters, reflecting the aerobic and endurance-oriented nature of their training, which stimulates both the cardiovascular and respiratory systems. Their FEV_1/FVC and $FEF_{25-75}\%$ ratios were significantly greater than those of volleyball players, suggesting better airway function and expiratory flow capacity. The volleyball players, who engage in high-intensity intermittent efforts, also displayed significantly higher PEF and MVV values compared with sedentary participants, indicating sport-specific adaptations in respiratory muscle strength and ventilatory efficiency.

No significant intergroup differences were found for FVC and VC, suggesting that total lung volume may be more influenced by anatomical and genetic factors than by training modality. Nonetheless, the consistent superiority of active groups over sedentary controls demonstrates that both aerobic (cross-country skiing) and anaerobic (volleyball) exercise contribute positively to pulmonary performance, albeit through distinct physiological pathways.

Figure 1

Comparison of Respiratory Parameters among Female Cross-Country Skiers, Volleyball Players, and Sedentary Participants (mean values).



Bar chart represents the mean values of each respiratory parameter (FVC, FEV_1, FEV_1/FVC%, PEF, FEF_{25-75}%, VC, MVV) for the three groups. Cross-country skiers generally exhibited higher values across most parameters, reflecting superior ventilatory and expiratory performance compared with volleyball players and sedentary women.

Table 3

Pearson Correlation Coefficients between Anthropometric Characteristics and Respiratory Function Parameters among Participants.

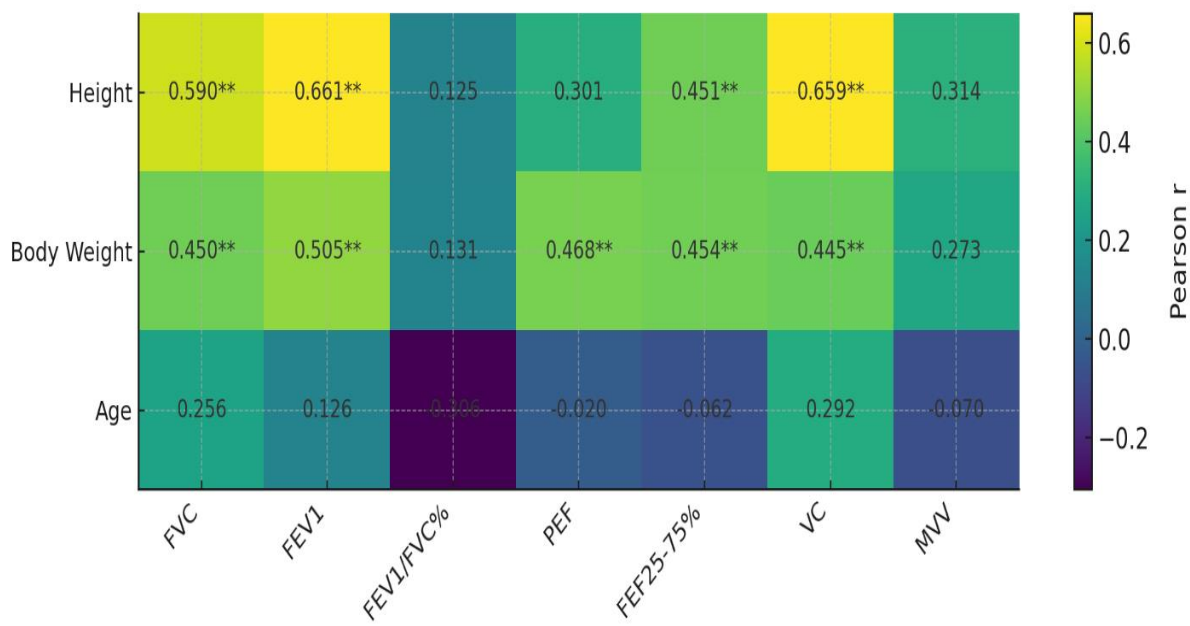
		FVC(L)	FEV1(L)	FEV1/FVC%	PEF (L/s)	FEF25-75% (L/s)	VC (L)	MVV (L/min)
Height	r	.590**	.661**	0.125	0.301	.451**	.659**	0.314
	p	0.000	0.000	0.469	0.075	0.006	0.000	0.062
Body Weight	r	.450**	.505**	0.131	.468**	.454**	.445**	0.273
	p	0.006	0.002	0.446	0.004	0.005	0.006	0.108
Age	r	0.256	0.126	-0.306	-0.02	-0.062	0.292	-0.07
	p	0.131	0.464	0.07	0.906	0.719	0.084	0.684

FVC (Forced Vital Capasity), FEV1(Forced Expiratory Volume in 1 second), FEV1(Forced Expiratory Volume in 1 second) /FVC (Forced Vital Capasity), PEF (Peak Expiratory Flow), FEF25-75% (Forced Expiratory Flow at 25-75%), VC (Vital Capacity) and MVV (Maximal Voluntary Ventilation)

Significant positive correlations were found between height and several respiratory parameters, including FVC, FEV_1, FEF_{25-75}%, and VC ($p < 0.01$). Body weight was also positively associated with FVC, FEV_1, PEF, and FEF_{25-75}% ($p < 0.01$). No significant correlations were observed between age and any respiratory variables. These findings indicate that taller and heavier individuals generally exhibit greater lung volumes and ventilatory capacities.

Figure 2

Correlation Heatmap between Anthropometric Characteristics (height, body weight, and age) and Respiratory Function Parameters.



The figure illustrates Pearson's correlation coefficients (r) between anthropometric and respiratory variables. Darker colors indicate stronger positive relationships. Significant correlations are marked with ** ($p < 0.01$) and * ($p < 0.05$). Height and body weight showed strong positive associations with several respiratory parameters, whereas age exhibited no significant correlation.

DISCUSSION

This section dives deep into the interpretation and significance of the findings presented in the 'Results'. It seeks to situate the research outcomes within the broader scholarly conversations, thereby offering insights into their implications, potential applications, and future directions. In the present study, the effects of sport-specific training on respiratory function were examined by comparing female cross-country skiers, volleyball players, and sedentary participants. The results revealed that the cross-country skiing group demonstrated enhanced ventilatory performance, with significantly higher FEV_1, FEV_1/FVC, PEF, $FEF_{25-75}\%$, and MVV values than sedentary women. These findings indicate that sustained endurance-oriented training induces substantial improvements in respiratory efficiency and expiratory flow dynamics. Moreover, the higher FEV_1/FVC and $FEF_{25-75}\%$ ratios observed in cross-country skiers compared with volleyball players suggest sport-specific adaptations that favor endurance capacity. In contrast, volleyball players showed moderately elevated PEF and MVV values relative to sedentary individuals, reflecting functional improvements linked to the intermittent, high-intensity demands of volleyball-specific exercise.

These findings are supported by previous research emphasizing the beneficial effects of endurance training on pulmonary function. Prakash et al. (2007) reported that long-term aerobic exercise enhances FEV_1 and vital capacity by strengthening respiratory musculature and improving alveolar efficiency, while Mazic et al. (2015) observed higher ventilatory capacity and oxygen transport efficiency in endurance-trained athletes compared with non-athletes. Together, these results reinforce the notion that regular, high-volume aerobic exercise elicits profound respiratory adaptations through continuous ventilatory stimulation. Further supporting this evidence, Sable et al. (2012) and Ahmadi et al. (2013) reported that consistent physical activity improves key lung function parameters. The superior FEV_1/FVC and $FEF_{25-75}\%$ values in cross-country skiers can be explained by the continuous respiratory and cardiovascular load imposed by endurance-based training, which strengthens respiratory musculature and enhances ventilatory capacity. In line with this, Bilici and Türker (2019) highlighted that endurance exercise strengthens respiratory muscles and increases ventilation efficiency, while Koubaa et al. (2015) found that long-term, low-intensity exercise improves FEV_1 and $FEF_{50}\%$, reflecting better airway conductance. Collectively, these findings underline the decisive role of endurance training in promoting pulmonary function among female athletes.

The higher PEF and MVV values observed in volleyball players compared with sedentary participants can be attributed to the explosive and intermittent nature of volleyball, which intermittently engages respiratory muscles under high ventilatory stress. Similar outcomes were reported by Mehrotra et al. (1998), who found that athletes had superior FVC, FEV_1, and PEF values compared with sedentary controls, and by Shashi et al. (2013), who demonstrated that high-intensity swimming training enhances MVV and PEF. These findings suggest that high-intensity, intermittent activities contribute to improvements in the dynamic components of respiratory function.The variation between endurance- and strength-oriented sports emphasizes the principle of training specifically in physiological adaptation. Vaithiyanadane et al. (2012) observed significantly greater lung function in swimmers than in sedentary individuals, whereas Bilici and Genç (2020) found that regular physical activity among university students led to improvements in FVC, VC, FEV_1, and PEF. These consistent findings confirm that distinct exercise modalities elicit unique respiratory adaptations depending on the dominant energy system and muscular involvement.

In summary, endurance-based sports such as cross-country skiing-characterized by sustained aerobic loading-play a key role in improving overall respiratory capacity, whereas power- and intermittently focused sports such as volleyball primarily enhance dynamic ventilatory performance. This differentiation reflects the diversity of physiological adaptations elicited by various training stimulus. As noted by Bilici and Genç (2020), individuals who participate in regular physical activity exhibit superior respiratory function compared with their sedentary counterparts, highlighting the broad positive influence of sport participation on pulmonary health. Understanding how exercise type, duration, and intensity shape these adaptations can aid in the design of evidence-based, sport-specific training models that optimize respiratory efficiency and athlete well-being.

Conclusion

In conclusion, this study demonstrated that regular engagement in sport-specific training produces measurable improvements in respiratory function among female athletes. Cross-country skiers, who predominantly perform endurance-based exercise, exhibited superior ventilatory and expiratory performance compared with volleyball players and sedentary participants. These outcomes confirm that long-term aerobic training exerts a stronger influence on pulmonary capacity and respiratory muscle efficiency than intermittent, power-oriented training forms. At the same time, the elevated PEF and MVV values in volleyball players indicate that high-intensity intermittent activity also enhances dynamic respiratory performance.

Overall, the results underscore that the type, duration, and intensity of exercise determine the nature of respiratory adaptations. Designing training programs that align with the physiological demands of each sport is essential for maximizing athletic performance and maintaining respiratory health. Future research should expand on these findings by including larger, more diverse athlete populations to further clarify the mechanisms underlying sport-specific respiratory adaptations and to refine evidence-based exercise prescriptions for both competitive and recreational settings.

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Author(s)' statements on ethics and conflict of interest

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