



Spirometric parameters and their relationship to body mass index across sport specializations in male student athletes: A cross-sectional study

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ABSTRACT

Background: Spirometric parameters are sensitive to the type and volume of habitual physical training, yet comparative data across different sports in non-elite student athletes, particularly in relation to body mass index (BMI), remain limited. **Aims:** To compare computer-assisted spirometric parameters in male university students engaged in different sports and to evaluate their associations with BMI. **Methods:** Thirty male university students were compared across three groups by sport specialization: mini-football (n=8), basketball (n=10), and cycling (n=12). External respiration was assessed by computer spirometry (PC Spirometry Set, Switzerland); FVC, IRV, ERV, VC, MVV, and TV were analyzed. Group differences were tested with the Kruskal-Wallis test followed by Dunn's post-hoc test (Holm correction); associations with body mass index (BMI) were assessed by Spearman correlation. Physiologically implausible values were excluded before analysis. **Result:** Maximal voluntary ventilation differed significantly between groups ($p = 0.004$): it was lowest in basketball players, who differed significantly from both mini-football and cyclic-sport athletes. Tidal volume also differed ($p = 0.026$), being higher in cyclic-sport athletes than in basketball players. Differences in vital capacity showed only a non-significant trend ($p = 0.055$), and FVC, IRV, and ERV did not differ between groups. BMI showed no statistically significant correlation with any spirometric parameter (all $p > 0.05$). **Conclusion:** In male student athletes, ventilatory indices — particularly maximal voluntary ventilation and tidal volume — differed by sport specialization, with the lowest values in basketball players, whereas BMI was not associated with spirometric parameters. The absence of a BMI-spirometry association is consistent with the limited value of BMI as a body-composition marker in athletes, and sport specialization should be taken into account when interpreting spirometry in this population.

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INTRODUCTION

The functional state of the respiratory system is an important determinant of physical performance, and its assessment is particularly relevant in young athletes who are still completing biological maturation while undergoing systematic training. Spirometric parameters – lung volumes, capacities, and ventilatory reserves – are sensitive to the type and volume of habitual physical training, and spirometry provides an accessible and non-invasive means of assessing the functional and adaptive capacity of the cardiorespiratory system (Segizbaeva & Aleksandrova, 2020; Köchli et al., 2019).

Different sports impose qualitatively different demands on pulmonary ventilation. In cyclic (endurance) disciplines, the aerobic component predominates, and prolonged rhythmic loads are associated with a more economical breathing pattern and larger ventilatory reserves (Durmic et al., 2015; Lazovic et al., 2015). In team sports, ventilation is exposed to continuously varying exercise intensity, with repeated transitions between submaximal and near-maximal efforts. Trained individuals are reported to display greater respiratory muscle strength and higher ventilatory output than untrained peers (Segizbaeva & Aleksandrova, 2020), and forced vital capacity has been shown to relate to maximal oxygen uptake in athletes (Lorenzo-Capellá et al., 2026), underscoring the functional relevance of spirometric indices for performance (Lazovic et al., 2018).

Body mass index is widely used as a simple anthropometric marker, and in the general population increased adiposity is accompanied by measurable reductions in expiratory reserve volume and other lung volumes (Jones & Nzekwu, 2006). However, simple anthropometric indices provide only an imperfect estimate of body-fat content (Belarmino et al., 2015), and in athletic populations BMI is particularly ambiguous, since an elevated value may indicate greater lean (muscle) mass rather than fat accumulation. Available data on body build, BMI, and functional fitness in students remain heterogeneous (Bogdanov et al., 2022; Galaktionova et al., 2023), and recent work has drawn attention to shifting BMI distributions among young athletes (Suvi et al., 2026). Despite this interest, comparatively few studies have simultaneously contrasted respiratory function parameters across athletes of different specializations and examined how these parameters relate to BMI within the same cohort. Most available evidence concerns elite athletes or clinical populations (Mazic et al., 2015; Lazovic et al., 2018; Bernhardsen et al., 2023), whereas university students who train regularly but are not professional athletes remain underrepresented, and directly comparable spirometric data for this group are scarce.

Clarifying these relationships in student athletes would help to interpret spirometric findings in the context of both training modality and body composition, and to avoid attributing to fitness what may partly reflect anthropometric differences. Accordingly, the aim of the present study was to characterize spirometric parameters in male university students engaged in different sports (mini-football, basketball, and cyclic disciplines) and to evaluate their associations with BMI. We hypothesized that (a) cyclic-sport athletes would show greater ventilatory capacity – higher vital capacity, maximal voluntary ventilation, and tidal volume – than representatives of team sports, and (b) BMI would be inversely associated with reserve respiratory indices.

METHOD

Research Design

This was an observational, cross-sectional comparative study examining respiratory function parameters across athletes of different sport specializations and their association with body mass index (BMI). The study was designed and reported in accordance with the STROBE recommendations for observational studies.

Participants

Thirty male university students aged 18-22 years were included in the analysis. Participants were recruited from the representative sports teams of Privolzhsky Research Medical University (Nizhny Novgorod, Russia). They were allocated into three groups according to their sport specialization: mini-football players (n=8), basketball players (n=10), and athletes engaged in cyclic/endurance sports (runners, swimmers, and other endurance disciplines; n=12). All participants were members of their university's representative teams in the respective sport and trained on a standardized schedule of three 90-minute sessions per week; some additionally

attended optional resistance-training sessions, which were not quantified. Training experience varied, averaging approximately 10 years, with most athletes having started at school age and a minority beginning at university. No formal a priori sample-size calculation was performed; the sample comprised all eligible members of the university teams available during the study period (a convenience sample).

Inclusion criteria were male sex, age 18-22 years, and regular training in the respective sport as a member of a university sports section. Exclusion criteria were any chronic respiratory disease (e.g., bronchial asthma) or chronic cardiovascular disease; an acute respiratory infection within the four weeks preceding examination; current tobacco smoking; and any other acute condition or contraindication to forced spirometry maneuvers. Students not engaged in organized sport were not eligible. Thus, all participants were apparently healthy, nonsmoking young men who trained regularly. All participants were informed in detail about the aims and procedures of the study and provided written informed consent prior to participation.

Instrument

Respiratory function was assessed by computer spirometry using the PC Spirometry Set hardware-software complex (Switzerland). Six parameters were analyzed: forced vital capacity (FVC), inspiratory reserve volume (IRV), expiratory reserve volume (ERV), vital capacity (VC), maximal voluntary ventilation (MVV), and tidal volume (TV). To ensure measurement accuracy and reproducibility, the device was calibrated before each examination session with a 3-L calibration syringe according to the manufacturer's instructions. Vital capacity was recorded with a slow (relaxed) expiratory maneuver, whereas forced vital capacity was obtained from a separate forced (maximal-effort) maneuver. Body height and mass were measured with standard equipment, and body mass index was calculated as body mass divided by height squared (kg/m^2).

Procedures

Data were collected in July–August 2026. Eligibility and health status were verified before testing by a pre-participation questionnaire and review of the students' sports medicine (medical examination) records. Examinations were performed in the first half of the day under resting conditions; participants refrained from intense physical activity during the 24 h preceding testing. Anthropometric measurements (body height and mass) were taken first, after which BMI was calculated. Spirometry was then performed in a seated position with a nose clip in place. Before recording, each participant received a standardized explanation and demonstration of the maneuvers and then performed several attempts, and the best technically acceptable result was retained for analysis. All measurements were carried out by a functional-diagnostics specialist using the same calibrated device throughout the study.

Statistical Analysis

Data were processed in Microsoft Excel 2016 and Statistica 10.0 (StatSoft). Before analysis, records were screened for physiologically implausible values (e.g., expiratory reserve volume exceeding vital capacity, forced vital capacity above the slow vital capacity, or zero values for tidal volume, inspiratory reserve volume, or maximal voluntary ventilation); such individual values were treated as missing and excluded, so the number of valid observations varies across parameters. Results are reported as median [interquartile range] and, for reference, as mean $\pm$ standard deviation. Because of the small group sizes and non-normal distribution of several variables, nonparametric methods were used. Between-group differences were assessed with the Kruskal–Wallis test, with η^2_H as a measure of effect size; where the overall test was significant, pairwise comparisons were performed with Dunn's post-hoc test with Holm correction for multiple comparisons. Associations between BMI and spirometric parameters were assessed using Spearman's rank correlation coefficient, with 95% confidence intervals. A two-sided $p < 0.05$ was considered statistically significant.

Table 1. Spirometric Parameters by Sport Group, Median [IQR] (Mean $\pm$ SD)

Parameter	Mini-football (n=8)	Basketball (n=10)	Cyclic (n=12)	H	p	η^2_H
FVC, L	4.25 [3.97–4.49] (4.32 $\pm$ 0.71)	4.23 [3.83–4.40] (3.98 $\pm$ 0.70)	4.38 [3.54–4.67] (4.16 $\pm$ 0.78)	0.24	0.886	–
IRV, L	1.99 [1.40–2.38] (1.92 $\pm$ 0.79)	1.96 [1.14–2.11] (1.62 $\pm$ 0.73)	1.89 [1.14–2.04] (1.68 $\pm$ 0.70)	0.48	0.787	–
ERV, L	1.69 [1.21–1.90] (1.46 $\pm$ 0.71)	1.37 [0.94–1.93] (1.37 $\pm$ 0.70)	1.27 [1.14–1.77] (1.56 $\pm$ 0.62)	0.22	0.897	–
VC, L	4.60 [4.19–5.48] (4.87 $\pm$ 1.00)	3.96 [3.58–4.55] (4.03 $\pm$ 0.62)	4.90 [4.31–5.35] (4.79 $\pm$ 0.74)	5.81	0.055	0.15
MVV, L/min	109.6 [100.9–120.5] (114.1 $\pm$ 19.1)	82.7 [72.0–93.8] (84.4 $\pm$ 16.3)*#	107.2 [98.3–133.2] (115.4 $\pm$ 30.3)	11.27	0.004	0.36
TV, L	1.42 [1.05–1.56] (1.27 $\pm$ 0.49)	1.19 [0.96–1.35] (1.14 $\pm$ 0.39) #	1.71 [1.41–1.92] (1.71 $\pm$ 0.51)	7.27	0.026	0.21

Note. Values are median [interquartile range] with mean $\pm$ SD in parentheses. Group differences were tested with the Kruskal–Wallis test (H, p) with η^2_H as effect size; significant effects were followed by Dunn's post-hoc test with Holm correction. * $p < 0.05$ vs mini-football; # $p < 0.05$ vs cyclic. Cell n varies because physiologically implausible values were excluded (see Methods). FVC – forced vital capacity; IRV – inspiratory reserve volume; ERV – expiratory reserve volume; VC – vital capacity (slow); MVV – maximal voluntary ventilation; TV – tidal volume.

Table 2. Spearman Correlations between BMI and Spirometric Parameters (Whole Sample)

Parameter	n	r_s	95% CI	p
FVC	26	0.16	[–0.24; 0.51]	0.437
IRV	28	0.32	[–0.06; 0.62]	0.101
ERV	27	–0.02	[–0.4; 0.36]	0.905
VC	29	0.18	[–0.2; 0.51]	0.361
MVV	29	–0.02	[–0.38; 0.35]	0.916
TV	28	0.03	[–0.35; 0.39]	0.898

Note. r_s – Spearman's rank correlation coefficient. No correlation reached statistical significance (all $p > 0.05$)

Scope and/or Limitations of the Methodology

The chosen cross-sectional design permits comparison of the functional state of the respiratory system between groups and assessment of its association with BMI, but does not allow causal inference. Spirometry characterizes respiratory function at rest and does not capture the ventilatory response to exercise; parameters are reported as absolute values without adjustment to percent-predicted. A fuller account of the study's limitations is given in the Limitation subsection of results and discussion.

Ethical Approval

The study was approved by the Local Ethics Committee of Privolzhsky Research Medical University (Nizhny Novgorod, Russia; Protocol No. 8, dated 14 August 2026) and was conducted in accordance with the World Medical Association Declaration of Helsinki (2013 revision). All participants provided written informed consent prior to inclusion. The study did not involve animals.

RESULTS AND DISCUSSION

Results

The three groups were comparable in age (18-22 years) and did not differ significantly in height (mini-football 178.4 ± 5.9 cm, basketball 180.1 ± 9.1 cm, cyclic 181.4 ± 3.7 cm; $p=0.326$), body mass (73.7 ± 8.9 , 71.7 ± 8.9 , and 80.2 ± 13.0 kg, respectively; $p=0.131$), or body mass index (23.2 ± 3.2 , 23.1 ± 2.8 , and 24.4 ± 3.5 kg/m²; $p=0.554$). Group comparisons of spirometric parameters are summarized in Table 1.

Forced vital capacity, inspiratory reserve volume, and expiratory reserve volume did not differ significantly between groups (all $p>0.78$), and the corresponding effect sizes were negligible ($\eta^2_H < 0$). Median forced vital capacity was similar across groups (mini-football 4.25 L, basketball 4.23 L, cyclic 4.38 L). Vital capacity showed a non-significant trend toward between-group differences ($H=5.81$, $p=0.055$, $\eta^2_H=0.15$), with the lowest values in basketball players (median 3.96 L) and comparable values in mini-football (4.60 L) and cyclic-sport athletes (4.90 L).

Maximal voluntary ventilation differed significantly between groups ($H=11.27$, $p=0.004$), with a large effect size ($\eta^2_H=0.36$). It was lowest in basketball players (median 82.7 L/min), and post-hoc comparisons showed that this group had significantly lower MVV than both mini-football players (114.1 L/min; $p=0.012$) and cyclic-sport athletes (115.4 L/min; $p=0.012$), whereas mini-football and cyclic-sport athletes did not differ from each other ($p=0.816$). Tidal volume also differed between groups ($H=7.27$, $p=0.026$), with a moderate-to-large effect size ($\eta^2_H=0.21$); it was highest in cyclic-sport athletes (median 1.71 L) and significantly higher in this group than in basketball players (1.19 L; $p=0.025$), whereas the difference from mini-football players did not reach significance ($p=0.212$).

The associations between BMI and spirometric parameters are shown in Table 2. None of the correlations reached statistical significance (all $p>0.05$). The coefficients were close to zero for expiratory reserve volume ($r_s=-0.02$), maximal voluntary ventilation ($r_s=-0.02$), and tidal volume ($r_s=0.03$), and weak and positive for inspiratory reserve volume ($r_s=0.32$, $p=0.101$), forced vital capacity ($r_s=0.16$), and vital capacity ($r_s=0.18$); all 95% confidence intervals included zero. Thus, BMI was not significantly associated with any spirometric parameter in this sample.

Discussion

The main finding of this study is that ventilatory function differed between sport groups – most clearly for maximal voluntary ventilation and tidal volume – whereas body mass index was not associated with spirometric parameters. Basketball players showed the lowest MVV, differing significantly from both mini-football and cyclic-sport athletes, and the lowest tidal volume. Because of the cross-sectional design, these differences should be interpreted as associations linked to sport specialization rather than as effects caused by training. The lower ventilatory output of the basketball group may reflect the intermittent character of the sport, in contrast to the more sustained rhythmic ventilation of cyclic disciplines. However, this interpretation remains tentative given the small and heterogeneous groups. Anthropometric factors such as stature may also contribute to between-group differences in lung volumes and should be considered as potential confounders (Lazovic-Popovic et al., 2016). Between-sport differences in ventilatory parameters have been reported previously (Durmic et al., 2015, 2017; Mazic et al., 2015; Hackett, 2020; Rajaure et al., 2023).

Vital capacity showed only a non-significant trend toward between-group differences, and forced vital capacity did not differ between groups. Across groups, forced vital capacity tended to be slightly lower than slow vital capacity; this is a recognized technical feature of the maneuvers rather than a sign of airflow obstruction, since the slow (relaxed) maneuver used to measure VC is often performed more completely than the forced maneuver, which requires specific skill and coached effort (Graham et al., 2019).

Contrary to our second hypothesis, BMI was not significantly associated with any spirometric parameter, and the point estimates were close to zero for the reserve indices. This absence of association is consistent with the view that BMI is a poor marker of body composition in athletes, in whom an elevated value may reflect greater lean mass rather than adiposity (Belarmino et al., 2015; Karaduman et al., 2022). Whereas increased adiposity reduces expiratory reserve volume in the general population (Jones & Nzekwu, 2006), the present participants were lean, physically active

young men with a relatively narrow BMI range, which may explain the lack of a detectable relationship. The heterogeneity of published data on body build, BMI, and functional fitness in students (Bogdanov et al., 2022; Galaktionova et al., 2023) is in line with this and argues for combining BMI with direct measures of body composition (Thomsen et al., 2025). A null result in a small sample must, however, be interpreted cautiously, as limited statistical power cannot exclude a weak association.

From an applied standpoint, the between-group differences in ventilatory indices support the use of spirometry as an accessible means of characterizing respiratory function in a sport-specific context (Lorenzo-Capellá et al., 2025, 2026). In contrast, the lack of a BMI association underscores that anthropometric indices alone are insufficient for this purpose. Continued attention to both anthropometric and respiratory monitoring in young athletes remains relevant (Suvi et al., 2026).

Implications

The findings have several practical implications for monitoring and training in student athletes. Because ventilatory indices (notably MVV and TV) differed by sport specialization whereas BMI did not, spirometric assessment can help characterize respiratory function in a sport-specific context rather than relying on generic reference values or on anthropometric indices such as BMI. The comparatively low ventilatory reserves of basketball players may deserve particular attention in monitoring and training planning. The accessible, non-invasive nature of computer spirometry makes it suitable for routine screening in this population.

Research Contribution

This study provides comparative spirometric data across three sport specializations within a single cohort of male university student-athletes, a group that remains underrepresented relative to elite athletes and clinical populations, and examines their relationship with BMI. It indicates that ventilatory parameters, rather than basic lung volumes or BMI, best distinguish athletes of different specializations, and that BMI is not a useful correlate of spirometric function in this population. The results provide a reference point for further studies of respiratory characteristics in non-elite athletes.

Limitations

Several limitations should be considered. First, the analysis was based on a verified subset of the original data: part of the dataset was no longer available, and individual values that were physiologically implausible (e.g., expiratory reserve volume exceeding vital capacity, or zero values) were excluded, reducing the sample to 30 athletes (8–12 per group) and yielding a variable number of valid observations per parameter. The small group sizes limit statistical power and the ability to detect smaller between-group differences or weak BMI associations, increasing the risk of false-negative findings. The cyclic-sport group was heterogeneous (runners, swimmers, and other endurance disciplines), which may have increased within-group variability. Only males in a narrow age range were studied, limiting generalizability to women and to other age groups. Body composition was characterized by BMI alone, without direct measures of fat and lean mass; spirometric values are reported as absolute values rather than as percentages of predicted values; and spirometry was performed at rest and does not capture the ventilatory response to exercise. The cross-sectional design precludes causal inference, and training volume and intensity were not quantified beyond specialization. Finally, the reproducibility of maneuvers was not formally evaluated against ATS/ERS acceptability criteria.

Suggestions

Future research should extend these findings in larger, adequately powered, multi-center samples that include female athletes and a wider age range, with more homogeneous sport groups. Complementing BMI with direct body-composition measures (e.g., bioimpedance or skinfold analysis) would clarify whether body composition relates to spirometric function more closely than BMI does (Bocharin et al., 2021). Longitudinal and interventional designs are needed to establish causal relationships between training modality, body composition, and respiratory function (HajGhanbari et al., 2013; Kowalski et al., 2024). Adding exercise ventilatory testing (e.g.,

cardiopulmonary exercise testing) would allow the resting spirometric differences observed here to be related to functional performance.

CONCLUSION

In male student athletes, spirometric parameters differed by sport specialization mainly in ventilatory indices, such as maximal voluntary ventilation and tidal volume—rather than in basic lung volumes; specifically, maximal voluntary ventilation was significantly lower in basketball players than in mini-football and cycling-sport athletes, who did not differ from each other, with basketball players also showing the lowest tidal volume, reflecting the intermittent versus sustained ventilatory demands of the respective sports. Furthermore, BMI was not significantly associated with any spirometric parameter, which is consistent with the limited value of BMI as a marker of body composition in athletes. Consequently, sport specialization, rather than BMI, should be taken into account when interpreting spirometry in student athletes, though larger studies are needed to confirm these findings.

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AUTHOR CONTRIBUTION STATEMENT

IB, MG, and AM conceived and designed the study. IB, MG, AG, and NR performed the examinations and collected the data. ER and IB carried out the statistical analysis and interpreted the results. IB wrote the original draft. AM, MG, and ER reviewed and edited the manuscript. All authors have read and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

The authors used Claude (Anthropic) during the preparation of this work for translation of the manuscript from Russian into English and for language editing. After using the tool, the authors thoroughly reviewed and edited the content as needed and take full responsibility for the content of the publication.

CONFLICTS OF INTEREST

The authors declare that they do not have any conflicts of interest related to the publication of this article, whether financial, institutional, or personal, that could influence the research process, analysis, writing, or publication of this manuscript.

ETHICAL APPROVAL

This study involving participants was approved by the Local Committee of Privolzhsky Research Medical University (Nizhny Novgorod, Russia; Protocol No.8, dated 14 August 2026). The study was conducted in accordance with the World Medical Association Declaration of Helsinki (2013 revision), and all participants provided written informed consent prior to inclusion. The study did not involve animals.

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