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Impact of Structured Aerobic Exercise on Symptom Burden and Lung Function in Adults with Asthma: A Prospective Cohort Study

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ABSTRACT

Objective: Asthma is a chronic respiratory condition characterized by airway inflammation and episodic airflow obstruction. While pharmacological treatments remain central to asthma management, aerobic exercise has gained attention for its potential benefits.

Materials and Methods: A prospective cohort study was conducted over 10 months at a primary healthcare facility, enrolling 64 adults diagnosed with asthma. Participants were assigned either to an intervention group, which engaged in structured aerobic exercise at least three times weekly, or to a control group that maintained their usual activity levels. Lung function was assessed every two months using spirometry, measuring forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and the FEV1/FVC ratio. Symptom severity was evaluated using a visual analogue scale.

Results: Of 116 eligible patients, 67 were enrolled (43 intervention, 24 control), with 64 completing the study. No significant baseline differences were observed between groups. The intervention group showed clinically meaningful reductions in symptom burden, particularly in morning symptoms (p=0.028), activity limitations (p=0.049), and asthma control satisfaction (p=0.042), each exceeding the minimal clinically important difference of ≥1.0. Lung function improved in the intervention group over time, with FVC and FEV1/FVC increasing (p=0.023; p=0.026), despite no significant between-group differences at individual time points.

Conclusion: This study highlights the potential of aerobic exercise as a complementary approach to asthma management. Incorporating structured physical activity into care may enhance symptom control and quality of life. Further research is needed to explore long-term benefits and optimize interventions for varying asthma severity.

Keywords: Asthma, aerobic exercise, lung, spirometry, physical activity, quality of life.

INTRODUCTION

Asthma is a chronic respiratory condition characterized by airway inflammation, bronchial hyperresponsiveness, and episodic airflow obstruction, affecting approximately 262 million people globally as of 2019.[1–3] While pharmacological treatments—such as inhaled corticosteroids and bronchodilators—remain central to asthma management, non-pharmacological strategies have gained increasing attention for their complementary benefits.[4] Among these, aerobic physical activity has been widely studied for its potential to improve outcomes beyond symptom relief. It enhances cardiorespiratory fitness, increases oxygen uptake, and reduces sedentary behaviors, contributing to overall health in individuals with asthma.[5] Moreover, regular exercise has been shown to lower systemic inflammation, a key factor in asthma pathophysiology, by reducing inflammatory markers such as interleukin-6 and C-reactive protein.[6] These changes are partly mediated by shifts in cytokine profiles, including increased levels of anti-inflammatory cytokines such as interleukin-10 (IL-10) and decreased levels of tumor necrosis factor-alpha (TNF-α), which collectively reduce airway inflammation.[7,8] Additionally, exercise can strengthen respiratory musculature and enhance ventilatory efficiency, potentially reducing airway resistance and improving symptom tolerance during physical exertion.[9] Exercise also supports mental well-being by alleviating anxiety and depression, conditions commonly reported in individuals with chronic diseases.[9] Despite these benefits, integrating aerobic exercise into asthma care presents challenges. Exercise-induced bronchoconstriction (EIB) and variability in individual tolerance require tailored regimens to maximize benefits and minimize risks.[10] Asthma symptoms, particularly EIB, can discourage physical activity, leading to sedentary behavior.[11] Nevertheless, recent studies indicate that structured aerobic exercise is associated with improved asthma control, reduced airway inflammation, and enhanced quality of life, supporting its role as a viable complementary strategy.[12–14] Kuder et al.[15] further emphasize that regular physical activity may reduce long-term morbidity and healthcare utilization in individuals with asthma. However, despite these encouraging findings, many existing studies suffer from methodological limitations that constrain generalizability. These include small sample sizes, heterogeneous exercise protocols, limited follow-up durations, and inadequate control of confounding variables. For instance, Eichenberger et al.[5] and Mendes et al.[13] included relatively small cohorts, limiting statistical power. Several studies applied varied exercise intensities and durations without standardization across participants,[14,16,17] and many were of short duration, making it difficult to evaluate long-term effects on asthma control.[12] Furthermore, the lack of randomized allocation in some observational or quasi-experimental studies[6,17] complicates the interpretation of causal relationships. These inconsistencies underscore the need for well-designed prospective studies with standardized interventions and clearly defined outcome measures to better understand the therapeutic value of aerobic exercise in asthma management.

KEY MESSAGES

- Aerobic exercise enhances asthma control – Regular structured aerobic activity significantly reduced morning symptoms and daily limitations in asthma patients.
- Selective improvements in lung function – The intervention group showed gains in FVC and FEV1/FVC ratio, despite no major changes in overall spirometry.
- Exercise as effective adjunct therapy – Aerobic exercise may improve symptom control and quality of life, supporting its integration as a non-pharmacological component of asthma management.

This prospective cohort study aims to assess the effects of aerobic exercise on asthma outcomes. By investigating changes in lung function and asthma control, we seek to provide insights into the potential of aerobic exercise as a complementary approach to asthma care.

We hypothesized that individuals participating in regular aerobic exercise would experience greater improvements in asthma control and respiratory function compared with the control group. Specifically, we expected a ≥10% improvement in the Forced Expiratory Volume in one second / Forced Vital Capacity (FEV1/FVC) ratio and a clinically significant reduction in morning symptoms, limitations in daily activities, and overall asthma control satisfaction in the intervention group compared with the control group over the 10-month period.

MATERIALS AND METHODS

Study Design

This prospective cohort study was conducted at a primary healthcare facility. The study, including its planning and implementation, received approval from the Institutional Ethics Committee (approval date: March 25, 2023; approval number: 01/1-732/1-23). Written informed consent was obtained from all participants prior to inclusion. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Participants

A total of 64 patients diagnosed with asthma were enrolled between September 2023 and October 2024. During the initial visit, participants were randomly assigned to the intervention (IG) or control group (CG) using a computer-generated sequence created in IBM SPSS Statistics version 23. The allocation sequence was concealed using sealed, opaque envelopes to prevent selection bias. No stratification or blocking was employed. The inclusion criteria were: (a) age over 18 years, and a (b) diagnosis of asthma for at least one year. All participants in both groups were managed according to established treatment guidelines, receiving a combination of inhaled corticosteroids and long-acting β2-agonists. Short-acting β2-agonists (e.g., salbutamol) were used as needed for symptom relief. Based on their prescribed therapy and clinical profiles, all participants met criteria corresponding to the Global Initiative for Asthma (GINA) Steps 2-3, indicating mild to moderate persistent asthma. Exclusion criteria were: (a) locomotor system impairments that could interfere with evaluation or the intervention protocol, (b) the presence of other chronic respiratory or cardiac diseases causing symptoms during exercise, and (c) irregular follow-up with a physician. Lung function was assessed every two months using spirometry (MIR Spirolab®) providing objective measurements of respiratory performance. In parallel, subjective symptomatology was evaluated using a Visual Analogue Scale (VAS), which allowed participants to quantify their perceived symptoms in a standardized manner. This dual approach enabled a comprehensive assessment of both physiological and subjective aspects of respiratory health over the course of the study. Due to the nature of the intervention, participants could not be blinded; however, outcome assessors conducting spirometry and the statistician performing data analysis were blinded to group allocation. Data were coded and anonymized prior to analysis to reduce measurement and analysis bias. Sample size estimation was performed using G*Power 3.1 software. Based on prior studies, we expected a medium effect size (Cohen's d=0.5) in spirometric outcomes, specifically the FEV1/FVC ratio. With a significance level of α=0.05 and a power of 80%, the required sample size was calculated as 52 (26 per group). To allow for a potential dropout rate of up to 20%, we aimed to enroll at least 62 participants.

Exercise Intervention

Participants assigned to the intervention group engaged in one or more aerobic exercises at least three times per week. These included walking 5 kilometers, running 3 kilometers, or cycling 10 kilometers. Each participant in the intervention group combined at least two forms of aerobic activity, such as walking, running, or cycling, allowing flexibility while ensuring consistent engagement in aerobic physical activity. To monitor compliance, participants were asked to maintain individual exercise diaries, recording the type, duration, and frequency of aerobic activities performed. These diaries were reviewed by the study team during each follow-up visit (every two months) to assess adherence to the intervention protocol.

Assessments of Lung Function and Symptoms Severity

Spirometry was conducted every two months over the course of 10 months for both groups, resulting in six measurement points (baseline, and at 2, 4, 6, 8, and 10 months). During each assessment, key parameters such as FEV1, FVC, and the FEV1/FVC ratio, were measured and recorded. At each visit, patients also completed a VAS to evaluate their perceived symptoms. The scale ranged from 1 to 10, with 10 indicating the most severe manifestation of symptoms. It included several statements and one question aimed at evaluating different aspects of symptom severity and asthma control:

- "Because of asthmatic symptoms, I often wake up at night." – VAS1
- "Symptoms are quite severe in the morning upon waking up." – VAS2
- "Asthma is limiting me in everyday activities." – VAS3
- "During the day, I feel shortness of breath." – VAS4
- "During the day, I feel wheezing in my chest." – VAS5
- "Because of asthmatic symptoms, I often use short-acting β2-agonists." – VAS6
- "How would you rate your overall satisfaction with asthma control?" – VAS7

This combined approach provided a comprehensive assessment of both objective lung function and subjective symptom burden.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, version 23.0 (IBM Corp., Armonk, NY, USA). Categorical data were presented as absolute and relative frequencies. The normality of quantitative data distribution was assessed through visual inspection of histograms. Potential outliers were evaluated using visual inspection of boxplots and descriptive statistics; no data points were excluded from the analysis. Data were reported as mean values with standard deviations. Differences from baseline were analyzed using two-way analysis of variance (ANOVA) with Bonferroni correction. Post hoc analysis was conducted using the paired Student's t-test (within groups) and the independent Student's t-test (between groups). For the evaluation of symptoms severity (VAS), deviations from normal distribution were observed. Consequently, all analyses

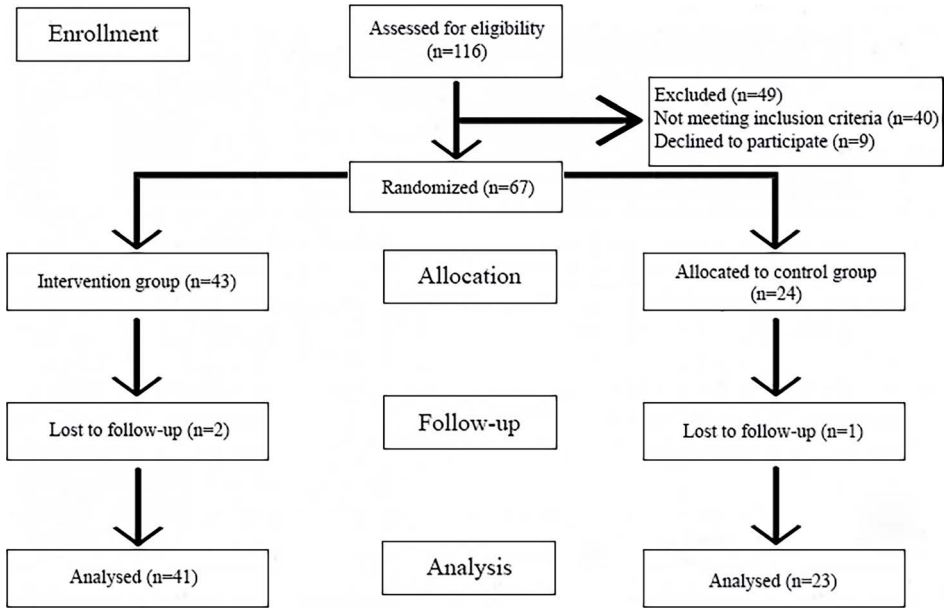

Figure 1. Flow diagram of the study.

were verified using corresponding nonparametric methods, including the Friedman two-way analysis of variance by ranks, the Wilcoxon signed-rank test, and the Mann-Whitney U test. No differences were found between the results obtained through parametric and nonparametric analyses; therefore, results are presented using parametric methods. Statistical significance for all observations, including symptoms severity and spirometry findings, was determined by comparing baseline values across different follow-up periods. For all tests (two-tailed), the level of significance was set at $p<0.05$.

RESULTS

A total of 116 patients with asthma were deemed eligible for the study, of whom 67 agreed to participate and met all inclusion criteria. Following randomization, 43 participants were assigned to the intervention group (IG) and 24 to the control group (CG). During the study, two participants from the IG and one from the CG were lost to follow-up due to irregular attendance. The study's flow diagram is presented in Figure 1.

Sociodemographic and Baseline Characteristics of the Participants

No statistically significant differences were observed in sex distribution between the groups (χ^2=0.092; p=0.762). Females constituted 65.9% (n=27) of participants in the intervention group and 69.6% (n=16) in the control group. Furthermore, baseline characteristics, including lung function parameters and perceived symptom burden assessed via VAS, did not differ significantly between the groups ($p>0.05$), as shown in Table 1.

Perceived Symptom Burden

Both groups demonstrated a reduction in symptom burden over time, as measured by the VAS, with the exception of VAS4 (p=0.056), VAS5 (p=0.249), and VAS6 (p=0.254). An overall statistically significant difference between the two groups across all measurement periods was observed for VAS2 (95% confidence interval [CI]=-1.67 to -0.10; p=0.028), VAS3 (95% CI=-2.64 to -0.69; p=0.049), and VAS7 (95% CI=-2.05 to -0.50; p=0.042), indicating that participants in the intervention group consistently reported lower symptom burden in these domains throughout the study. The average improvements in VAS2, VAS3, and VAS7 in the intervention group exceeded 1.0 points, meeting or surpassing the minimal clinically important difference (MCID) threshold for asthma-related VAS measures. Post hoc analysis provided detailed insights into the significant effects on changes in symptom burden within and between groups. The distribution of average symptom burden across observation variables and measurement periods is illustrated in Figure 2. At the final measurement, a significant difference in average symptom burden values between the two groups was observed across all observation variables, with the intervention group demonstrating more favorable outcomes, except for VAS5.

Lung Function

No statistically significant differences in spirometry results were observed between the two groups at any measured time point. However, in the third measurement period, a statistically significant improvement in FVC was observed in the intervention group compared with baseline values (95% CI:

Table 1. Mean and baseline values of symptom burden VAS and spirometry results at the beginning of the study

Results	Total N=64 Mean±SD[a]	Intervention group N=41 Mean±SD[a]	Control group N=23 Mean±SD[a]	p
Age (years, mean±SD)	43.3±12.7	42.3±12.4	44.1±13.2	0.521
Sex (% female)	67.2% (n=43)	65.9% (n=27)	69.6% (n=16)	0.762
VAS1	1.50±2.17	1.29±1.63	1.87±2.90	0.311
VAS2	1.97±2.14	1.61±1.36	2.61±3.01	0.073
VAS3	2.47±2.14	2.27±2.02	2.83±2.33	0.320
VAS4	1.97±1.80	2±1.70	1.91±2	0.855
VAS5	1.50±1.66	1.44±1.57	1.61±1.85	0.698
VAS6	1.34±1.94	1.29±1.95	1.43±1.97	0.782
VAS7	2.13±1.11	1.95±1.02	2.43±1.20	0.093
FEV1 (%)	90.50±16.66	90.61±16.91	90.30±16.56	0.945
FVC (%)	88.84±12.60	88.71±13.70	89.10±10.67	0.909
FEV1/FVC (%)	101.87±12.56	102.01±10.03	101.61±16.39	0.903

VAS: Visual Analogue Scale; VAS1-VAS7: Visual Analogue Scale items (score range: 1–10); FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEV1/FVC: Ratio of FEV1 to FVC. a: Data are presented as mean±standard deviation. Between-group comparisons were conducted using the independent Student's t-test or the Mann-Whitney U test, as appropriate. Statistical significance was set at p<0.005.

0.32 to 4.06; p=0.023). Additionally, in the fifth measurement period, the intervention group exhibited a significant increase in the FEV1/FVC ratio (95% CI: 0.35 to 5.13; p=0.026), again compared with baseline. These findings suggest that while no overall between-group differences were observed, the intervention group demonstrated improvements in specific spirometric parameters over the course of the study (Fig. 3).

DISCUSSION

The findings of this study underscore the therapeutic potential of aerobic exercise as a complementary intervention for asthma management. While no significant differences in spirometry parameters were observed between the intervention and control groups across most time points, the intervention group exhibited modest improvements in specific lung function markers, such as FVC and the FEV1/FVC ratio. These results align with growing evidence highlighting the role of regular physical activity in enhancing respiratory function and reducing asthma severity.[5,6] Aerobic exercise has been shown to strengthen respiratory muscles, improve oxygen uptake, and reduce airway hyperresponsiveness, mechanisms that collectively contribute to better asthma control.[9,15] Specifically, Mendes et al.[13] reported a 7–10% increase in FVC and a 6% improvement in the FEV1/FVC ratio following an 8-week aerobic training program in adults with asthma. Similarly, a recent Cochrane systematic review[18] identified consistent improvements in airway function following structured aerobic exercise, emphasizing its role in reducing EIB and enhancing respiratory endurance. Hansen et al.,[6] in a meta-analysis, reported pooled improvements of approximately 6.2% in FEV1 and 5.1% in FVC across exercise interventions of varying durations. Although our FEV1 did not significantly improve, the increase in the FEV1/FVC ratio suggests improved airway function, consistent with earlier reports. Our findings from the Visual Analogue Scale analysis further support the benefits of aerobic exercise. Modest improvements were observed in symptom domains such as morning severity, limitations in daily activities, and overall satisfaction with asthma control among participants in the intervention group. Importantly, these changes also exceeded the established MCID threshold of ≥1.0 to 1.5 points,[19,20] underscoring their clinical relevance. These results are consistent with those reported by Mendes et al.,[13] who observed reductions of 1.2 to 1.5 points in similar symptom domains as measured by patient-reported outcomes. Additionally, a study by Dogra and Baker[17] demonstrated that regular physical activity significantly alleviates perceived symptom severity, with participants reporting improved control over wheezing and shortness of breath, accompanied by subjective symptom improvements ranging from 1.0 to 1.4 points on the Visual Analogue Scale. However, certain domains in our study, such as shortness of breath during the day and wheezing, showed no significant improvement, mirroring findings from Nyenhuis et al.,[16] who reported variable VAS improvements, with wheezing and shortness of breath often remaining unchanged. These patterns, reflected in our results for VAS4 and VAS5, underscore the need for personalized exercise programs to address specific symptom burdens effectively. Beyond its physiological benefits, aerobic exercise

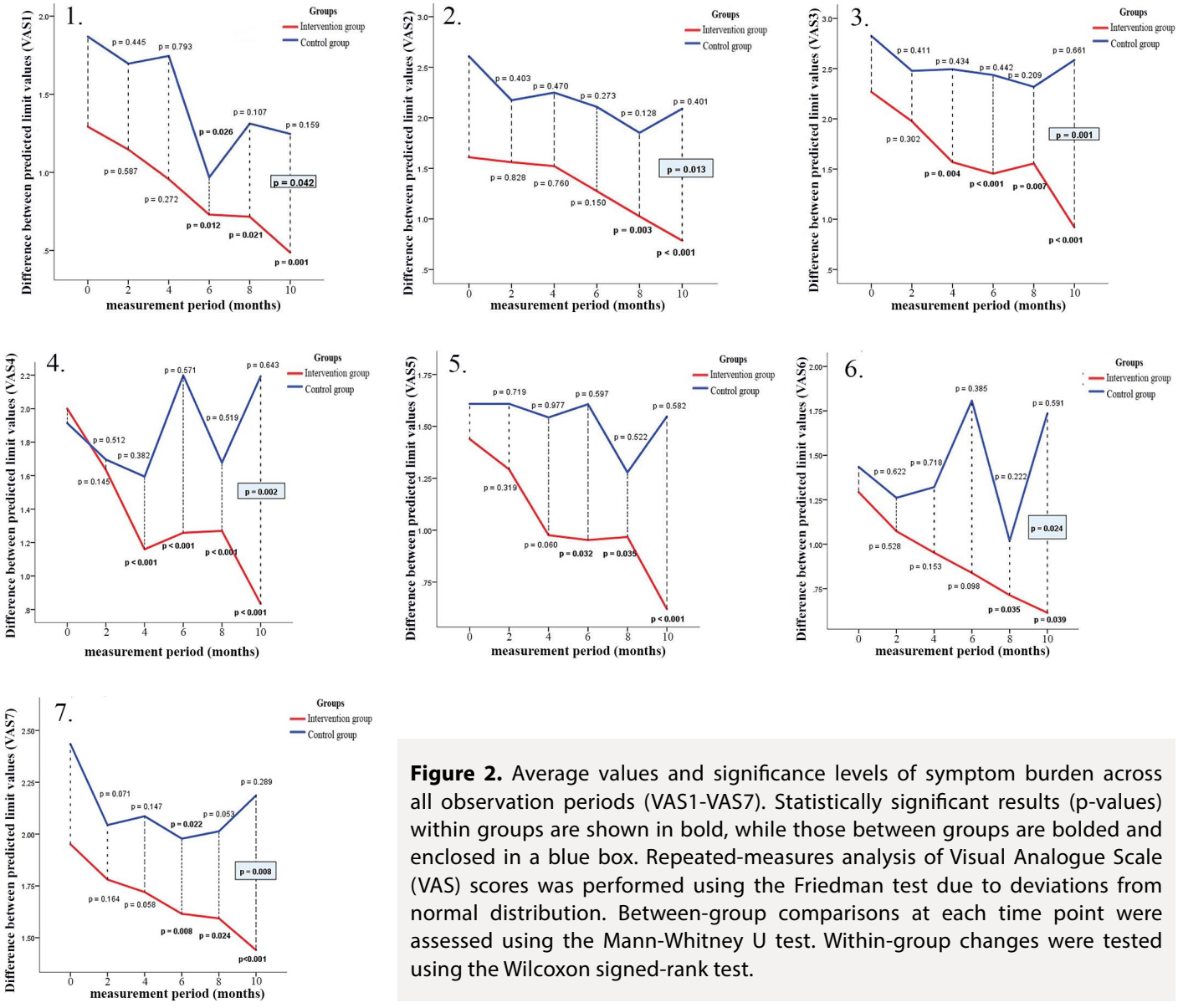

Figure 2. Average values and significance levels of symptom burden across all observation periods (VAS1-VAS7). Statistically significant results (p-values) within groups are shown in bold, while those between groups are bolded and enclosed in a blue box. Repeated-measures analysis of Visual Analogue Scale (VAS) scores was performed using the Friedman test due to deviations from normal distribution. Between-group comparisons at each time point were assessed using the Mann-Whitney U test. Within-group changes were tested using the Wilcoxon signed-rank test.

plays a critical role in addressing systemic inflammation, a key factor in asthma pathophysiology. Regular aerobic activity has been associated with reduced levels of pro-inflammatory cytokines such as interleukin-6 and tumor necrosis factor-alpha, which are often elevated in individuals with asthma. These anti-inflammatory effects not only alleviate airway inflammation but also contribute to broader improvements in cardiovascular health, which is often compromised in individuals with chronic respiratory conditions.[7,10] The psychological benefits of aerobic exercise are equally noteworthy. Chronic asthma is frequently accompanied by heightened levels of anxiety and depression, both of which can exacerbate symptom perception and reduce adherence to treatment regimens.[21] Exercise has been shown to alleviate these psychological burdens by modulating stress-related pathways and improving overall mood. This dual benefit—addressing both physical and mental health—positions aerobic activity as a holistic approach to asthma care.[14,16]

Despite these promising findings, implementing exercise interventions in asthma management is not without challenges. Individual variability in exercise tolerance, particularly in the presence of EIB, necessitates tailored regimens that consider patient-specific limitations and preferences. Studies have suggested that gradual increases in exercise intensity, combined with pre-exercise bronchodilator use, can mitigate the risk of EIB and enhance patient compliance.[22,23] Additionally, education and collaboration between healthcare providers and patients are essential to overcoming barriers to

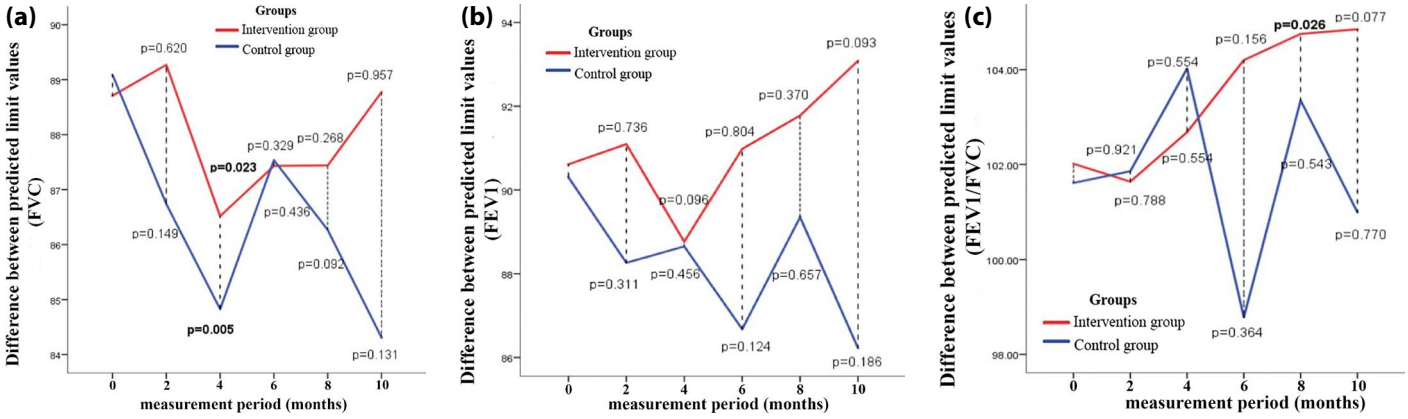

Figure 3. (a) Average values of forced vital capacity (FVC) across all measurement periods and significant differences compared with baseline values within groups. Data were analyzed using repeated-measures analysis of variance (ANOVA) with Bonferroni correction. Nonparametric tests confirmed the consistency of findings. **(b)** Average values of forced expiratory volume in one second (FEV1) across all measurement periods and significant differences compared with baseline values within groups. Data were analyzed using repeated-measures analysis of variance (ANOVA) with Bonferroni correction. Nonparametric tests confirmed the consistency of findings. **(c)** Average values of the ratio between forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) across all measurement periods and significant differences compared with baseline values within groups. Changes in the FEV1/FVC ratio were assessed using analysis of variance (ANOVA) with Bonferroni correction. Corresponding nonparametric tests (Wilcoxon signed-rank, Mann-Whitney U) were used for validation.

physical activity, such as fear of symptom exacerbation and lack of access to structured programs.[24] Future research should aim to refine exercise protocols further by investigating the comparative effectiveness of different types and intensities of aerobic activities. Exploring the molecular mechanisms underlying exercise-induced improvements in asthma outcomes could also pave the way for innovative therapeutic strategies. Furthermore, integrating exercise interventions with other lifestyle modifications, such as dietary changes, may yield synergistic benefits, providing a more comprehensive approach to asthma management.

This study has several limitations that should be acknowledged. First, the relatively small sample size and the homogeneity of the participant group may limit the generalizability of the findings to broader asthma populations. Our cohort consisted exclusively of adults with mild to moderate asthma, which restricts extrapolation to children, older adults, and individuals with severe or poorly controlled disease. Second, the study duration may not have been sufficient to fully capture the long-term effects of aerobic exercise on asthma management. Third, reliance on self-reported measures, such as the VAS, introduces potential subjective bias in symptom reporting. In addition, adherence to the exercise regimen was monitored through self-reported diaries, which may be susceptible to reporting inaccuracies or recall bias. Moreover, we used the VAS instead of a validated tool such as the Asthma Control Test (ACT) to assess symptom burden and asthma control. While the VAS allowed for detailed, domain-specific evaluation, this limits the standardization and comparability of our findings with other studies. Furthermore, we did not include objective markers of inflammation—such as fractional exhaled nitric oxide (FeNO) or cytokine levels—which would have offered valuable mechanistic insights into the observed clinical improvements. Also, Body Mass Index (BMI) was not assessed in this study, which limits the ability to examine the potential modifying effects of body weight on asthma outcomes and the response to aerobic exercise. To address these limitations, future studies should aim to recruit larger and more diverse populations, extend the follow-up period to assess sustained effects, incorporate validated asthma control questionnaires, and include objective biomarkers to provide a more comprehensive understanding of the physiological and clinical benefits of aerobic exercise in asthma care.

CONCLUSION

This study reinforces the evidence supporting aerobic exercise as an effective adjunct to traditional asthma treatments. By improving lung function, reducing systemic inflammation, and alleviating psychological distress, regular physical activity offers a multifaceted approach to enhancing asthma control and quality of life. Continued collaboration between clinicians, patients, and researchers will be critical for optimizing exercise-based interventions and maximizing their therapeutic potential.

Ethics Committee Approval: The Dom Zdravja Livno University Ethics Committee granted approval for this study (date: 25.03.2023, number: 01/1-732/1-23).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

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