Journal of Physical Education and Sport ® (JPES), Vol. 23 (issue 12), Art 373, pp. 3264- 3270, December 2023
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

The effect of combined continuous run, circuit training, and high-intensity interval training on lung function, asthma control, and VO2max in asthma patients: A quasi-experimental study

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Published online: December 31, 2023
(Accepted for publication : December 15, 2023)
DOI:10.7752/jpes.2023.12373

Abstract:
Background: The serious implications of asthma stem largely from inadequate control of the condition, affecting individuals with both regular and irregular physical activities. ***Objective*:** This study aims to assess the effect of Continuous Run (CR), Circuit Training (CT), and High-Intensity Interval Training (HIIT) over a 3-month period on reducing, controlling, and improving fitness in individuals with asthma. ***Methods:*** The research employed a quasi-experimental study design with a one-group pretest-posttest approach. The treatment involved physical exercise programs (CR, CT, and HIIT) conducted at the athletic field of Padang State University from June 2023 to August 2023. A total of 21 participants (16 males and 5 females) were recruited to participate in this research. They were chosen after meeting inclusion criteria—asthma diagnosis, physical inactivity, between 17 and 40 years old, willingness to refrain from other treatments except using an inhaler in case of relapse, and providing informed consent. Participants who willingly signed and completed the study were distributed to treatment groups, receiving the same exercise program with identical dosages and intensities of CR, CT, and HIIT. The exercise program lasted 75 minutes per session, three times a week for 12 weeks. Data were collected using several instruments. First, spirometry was employed to examine lung function (Forced Vital Capacity [FVC] and Forced Expiratory Volume in one second [FEV1]) with a cut-point of 0.75. Meanwhile, asthma symptom control was measured by the Asthma Control Questionnaire (ACQ), and VO2Max was assessed through a 2.4-kilometer run. The data were then analyzed using the Wilcoxon signed-rank test through the IBM SPSS Statistics version 25. ***Results:*** All participants completed the combined CR, CT, and HIIT exercise program over 12 weeks. Data analysis revealed significant improvement in lung function, with the average FVC score increasing from 61.62 ± 7.37 to 81.90 ± 4.06, representing a 35.52% increase. Furthermore, the pretest and posttest FVC results indicated an increase from 71.09 ± 4.75 to 90.00 ± 4.46, corresponding to a 27.17% reduction in FVC score, suggesting enhanced lung function. ACQ scores demonstrated a decrease from 1.58 ± 0.17 to 1.20 ± 0.13, representing a 23.34% reduction. Inferential statistical tests revealed significant differences ($P < 0.05$) between pretest and posttest values for FEV1, FVC, ACQ, and VO2Max in each group. ***Conclusion***: The CR, CT, and HIIT exercise program has been verified as effective in improving lung function, asthma control, and VO2Max. This study provides new insights into asthma treatment through CR, CT, and HIIT exercise programs.
Keywords: **Continuous run, circuit training, high-intensity interval training, asthma patients**

Introduction

Asthma is one of the most commonly encountered chronic diseases in adults and children, occurring frequently in both developed and developing countries (Majellano et al., 2019; Pavord et al., 2018). Individuals with asthma experience an elevated respiratory rate during exacerbations. Frequently, it leads to panic, anxiety, and stress, resulting in a heavier breathing rhythm (Kaneko et al., 2013; Pavord et al., 2018). This is attributed to chronic inflammation of the respiratory tract in asthma patients, characterized by wheezing, coughing, and recurring chest tightness, particularly at night or in the early morning due to airway obstruction (Majellano et al., 2019). The chronic inflammation is associated with airway hyperresponsiveness (excessive narrowing of the airways triggered by factors such as viruses, allergens, and excessive physical activity), causing intermittent wheezing, shortness of breath, coughing, and variable degrees of chest pain (Quirt et al., 2018). Scholars believe that the development and progression of asthma phenotypes are affected by various factors, including environmental elements, genetics, hygiene levels, and atopic status (Breuer & Wicker, 2009; Morjaria & Polosa, 2010).

Asthma can occur due to genetic factors, where specific genes in individuals with asthma can be hereditary (Pavord et al., 2018; Sakamoto & Hizawa, n.d.). These genetic factors can trigger asthma attacks when there are precipitating factors, either from within or outside of the body. Internal precipitating factors

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include respiratory infections, stress, excessive physical activity, and emotions. Meanwhile, external triggers consist of dust, pollen, animal dander, food, beverages, medications, odors, chemicals, air pollution, and weather or temperature changes (Gawlik et al., 2019). Of those factors, environmental conditions commonly provoke asthma attacks, including inhalation allergens found at home or in the workplace and inhalation irritants from air pollution, such as cigarette smoke, industrial emissions, and vehicle exhaust (Morjaria & Polosa, 2010). The current high prevalence of asthma and the potential asthma-inducing environmental conditions contribute to an increasing number of asthma cases in the future, posing a serious health issue (Lennelöv et al., 2019; Morjaria & Polosa, 2010). Asthma attacks can disrupt work for adults and interfere with learning activities for children (Kaneko et al., 2013). The prevalence of asthma continues to rise, especially in developing countries, due to lifestyle changes and increased air pollution (Tomisa et al., 2019). In Indonesia, according to Basic Health Research in 2013, the prevalence of asthma was reported to be 4.5% of the population, with a cumulative total of approximately 11,179,032 asthma cases. Asthma significantly affects disability and premature death, particularly in children aged 10-14 and adults aged 75-79.

In general, asthma-related deaths in developing countries are primarily attributed to poor control of the disease (Majellano et al., 2019). With effective control, asthma tends to be mild and does not significantly interfere with one's activities (Majellano et al., 2019). Unfortunately, efforts to control asthma in Indonesia have not been well-implemented (Rikesdas, 2018). Therefore, improving asthma control measures is crucial. Asthma remains a public health concern in almost all countries worldwide, affecting individuals from children to adults with varying degrees of severity. It can sometimes be fatal (Bush, 2019; Pugh et al., 2018; Wedell-Neergaard et al., 2018). Moreover, the global prevalence of asthma is rising, leading to substantial healthcare costs (Tomisa et al., 2019). Supported by WHO data, it is estimated that by 2025, there will be 255,000 deaths worldwide due to asthma, with this number expected to increase continuously because asthma is often undiagnosed.

One way to control asthma is by engaging in regular exercise to maintain physical fitness (Del Giacco et al., 2015; Onyshchuk et al., 2017). Regular physical activity has been proven to have numerous positive effects on chronic diseases, including asthma. It reduces the risk of cardiovascular diseases, diabetes, obesity, hypertension, and depression (WHO, 2011). However, the potential effects on asthma control are often misunderstood (Sillanpää et al., 2021). Consequently, recommendations to avoid exercise for asthma patients are commonly encountered in society due to the fear of exercise-induced asthma symptoms. Indeed, individuals with asthma must exercise caution during physical activities, as exercise can also act as a trigger for asthma attacks, known as exercise-induced asthma (EIA) (Gawlik et al., 2019).Recommended exercises for asthma patients are light and straightforward, meaning that the exercise should be well-planned and adapted to the individual's asthma condition. It should be based on exercise principles that train strength and endurance, improve VO2max, enhance lung function, and reduce the stress experienced by asthma patients. Suitable exercise for asthma patients includes breathing exercises (Yoga, asthma gymnastics), swimming, brisk walking, running, volleyball, casual cycling, and racket sports. However, recent research has also shown the feasibility of asthma patients engaging in high-intensity interval training (HIIT) (Toennesen et al., 2018). Furthermore, other studies have indicated that high-intensity exercise can reduce inflammation and improve the VO2Max of asthma patients (Winn et al., 2019; Toennesen et al., 2018). Certainly, High-Intensity Interval Training (HIIT) stands out as a highly effective training methodology for enhancing both aerobic and anaerobic capacities, along with inducing various physiological respiratory adaptations (Bossmann et al., 2023). In order to diversify the exercise regimen and further augment the aerobic and anaerobic capacities of individuals with asthma, it is essential to complement such training with strength-building exercises, such as CT. The utilization of CT is motivated by its capacity to enhance muscular strength, elevate metabolism, and align with the foundational principles of the training protocol (Pignato et al., 2019). This combination of exercises is posited to significantly improve lung function, enhance control, and elevate VO2Max in individuals grappling with asthma.

It can be clearly stated that understanding the pathophysiology of asthma is crucial for diagnosing and providing treatment for asthma patients (Bush, 2019). In asthma, there is an inflammatory process and hyperreactivity of the airways that facilitates the occurrence of airway obstruction. Additionally, there is damage to the epithelium of the airways, disturbances in the autonomic nervous system, and changes in the smooth muscle of the bronchi that play a role in the hyperreactivity of the airways. Airway obstruction occurs due to chronic inflammation in the airway walls, causing airflow to be severely limited, although recovery remains possible when appropriate management or treatment is administered (Quirt et al., 2018).

Bronchial reflex occurs due to the stretching of the vagus nerve. Meanwhile, the release of inflammatory mediators by mast cells and macrophages makes the airway epithelium more permeable, facilitating the entry of allergens into the submucosa and thereby intensifying the reaction. Mast cell involvement is not found in certain conditions, such as hyperventilation, inhalation of cold air, smoke, mist, and SO_2. Neural reflex plays a role in asthma reactions that do not involve mast cells. Stimulated efferent vagal nerve endings in the mucosa lead to the release of sensory neuropeptides such as substance P, neurokinin A, and calcitonin Gene-Related Peptide (CGRP). These neuropeptides cause bronchoconstriction, bronchial edema, plasma exudation, mucus hypersecretion, and activation of inflammatory cells (Lemanske & Busse, 2010).

As mentioned earlier, asthma patients can engage in various physical activities, including complex physical activities such as participating in specific sports, fitness management, athletics, soccer, and basketball.

It is a common understanding that individuals with a history of asthma may face difficulties in complex physical activities, posing a challenge for asthma sufferers. Although asthma cannot be completely cured, appropriate management can be implemented to control, reduce, and avoid the risks associated with symptoms. This research holds significant importance amid the problematic nature of asthma, necessitating an effective approach to reduce, control, and mitigate the risks associated with asthma symptoms. This aligns with the decision of the Minister of Health of the Republic of Indonesia regarding asthma control guidelines (Kemenkes RI, 2018). Additionally, this research is in line with the Minister of Health's regulations on the national action plan for non-communicable disease control, specifically addressing the prevalence of asthma concerning strategic actions and strategies (Ministerial Regulation, (Permenkes, 2017).

Based on the theories and paradigms mentioned above, the objectives of this research are (1) to develop a CR, CT, and HIIT exercise program to reduce, control symptoms, and mitigate the risks associated with asthma symptoms, (2) to assess the feasibility of the CR, CT, and HIIT exercise program in reducing, controlling symptoms, and mitigating the risks, and (3) to determine the effectiveness of the CR, CT, and HIIT exercise program in reducing, controlling symptoms, and mitigating the risks associated with asthma symptoms.

Material & methods

Research design

This research was conducted using a quasi-experimental design with an intervention group (without control) (Montgomery, 2013). The intervention program applied to the participants combined CR, CT, and HIIT with a specified exercise dosage.

Participants

Participants in this study were recruited using the accidental sampling technique with inclusion criteria: 1) individuals experiencing asthma and not engaging in physical activity, 2) between 17 and 40 years old, 3) having agreed not to undergo any other treatment besides the provided treatment, except for using an inhaler in case of relapse, 4) not using a bronchodilator < 8 hours, 5) asthma patients currently undergoing treatment; and 6) informed consent. Each participant signed an agreement to participate in the entire research process. On the other hand, exclusion criteria for this study included asthma patients with other diseases. Another criterion was that spirometer examination maneuvers that were performed > 3 times, and the results did not yield the two highest values of FEV1 and FVC with a difference of less than 5% or 100ml. With these inclusion criteria, 21 participants were chosen, comprising 16 males and 5 females.

Intervention Procedure

The first stage of this research began by obtaining research approval. Then, research brochures and a Google Form were provided to facilitate the recruitment of participants. Additionally, the research tool infrastructure and required coaching personnel were examined. Consent files and each individual had documentation for the measurements and treatments to be performed. Participants who were willing and had signed the consent form were followed throughout the study. After all research requirements were gathered, initial measurements (pre-test) were conducted at different times to determine the initial abilities of all participants. Subsequently, on different days, participants were provided the same treatment, with the same dosage and intensity as the CR, CT, and HIIT exercise program. The treatment lasted 75 minutes each session, including warm-up, core exercises, and cool-down. Participants received treatment with three exercise sessions per week for 12 weeks on the athletic field of Universitas Negeri Padang. Thus, a total of 36 training sessions were conducted. After each session ended, posttests were conducted on different days. The final stage of this research involves analyzing the data obtained descriptively and inferentially, which will be reported later in the research findings.

Measurement/Instruments

This research collected the data using several instruments. First, the spirometer version SP80B (Contec Medical System Co., Ltd) was employed to measure lung function (FVC=Forced Vital Capacity and FEV1=Forced Expiratory Volume). This tool was run in an operating environment with a temperature range of +10°C ~ +40°C, relative humidity not exceeding 80%, and atmospheric pressure between 700 hPa ~ 1060 hPa (see Figure 1). Following that, asthma symptom control was assessed using the Asthma Control Questionnaire (ACQ) (Juniper et al., 1999). Meanwhile, VO2Max was measured using the 2.4 running test.

Figure 1. Spirometer SP80B **(Contec Medical System Co., Ltd)**.

Statistical analysis

The data were analyzed using the Wilcoxon signed-rank test with Version 25 of the IBM Co. USA application. The normality of the data distribution was assessed using the Shapiro-Wilk method, and homogeneity was analyzed using an independent t-test. Meanwhile, to test the hypothesis, a paired t-test was conducted to examine the differences.

Results

The results of this study are presented sequentially. Results of descriptive data (see Table 1) and normality testing of the data (see Table 2) are presented first. They are followed by (2) Inferential statistical analysis using the Wilcoxon signed-rank test to demonstrate significant differences in the data, FEV1, FVC function, and ACQ (see Table 3).

The first part of this section provides the results of the descriptive data by presenting the minimum, maximum, total, average, and standard deviation of each pre- and posttest variable. The presented data include the decrease/increase in pre or posttest after treatment manipulation of CT, CR, and HIIT exercises, which are interventions in this study. This study found that the FEV1 level at the pretest had an average of 61.62 ± 7.37. Meanwhile, after treatment, the average FEV1 level increased to 81.90 ± 4.06 within the same group, with a percentage increase of 35.52%. Likewise, the results of the pretest and posttest in FVC showed an increase (71.09 ± 4.75 to 90.00 ± 4.46) with a percentage increase in FVC score, namely, 27.17%. These results indicate an improvement in lung function. Meanwhile, in the pretest and post-test ACQ results, a decrease was observed (1.58 ± 0.17 to 1.20 ± 0.13) with a percentage decrease of (23.34%), indicating an improvement in asthma control. For a clearer view, the descriptive results of this study can be seen in Table 1 and Figure 2.

Table 1. Description of the average results of each group in the pretest and posttest.

Group	*n*	Min	Max	*M* ± *SD*
Pre_FEV1	21	48.00	80.00	61.62 ± 7.372
Post_FEV1	21	75.00	91.00	81.90 ± 4.06
Pre_FVC	21	63.00	87.00	71.09 ± 4.75
Post_FVC	21	80.00	96.00	90.00 ± 4.46
Pre_ACQ	21	1.30	1.90	1.58 ± 0.17
Post_ACQ	21	1.00	1.50	1.20 ± 0.13
Pre_Vo2Max	21	12.2	19.1	16.36 ± 1.88
Post_Vo2Max	21	10.2	12.3	18.52 ± 24.00

Information: prep_FEV1: Pretest Forced Expiratory Volume in one second. Post_FEV1: Posttest Forced Expiratory Volume in one second. Pre_FVC: Pretest Forced Vital Capacity. Pos_FVC: Posttest Forced Vital Capacity. Pre_ACQ: Pretest Asthma Control Questionnaire. Post_ACQ: Posttest Asthma Control Questionnaire. Pre_Vo2Max: Prestes Volume Oxygen Maximal. Posttest_Vo2Max: Posttest Volume Oxygen Maximal. Min: Minimum Score, Max: Maximal Score, M: Mean. SD: Standard deviation.

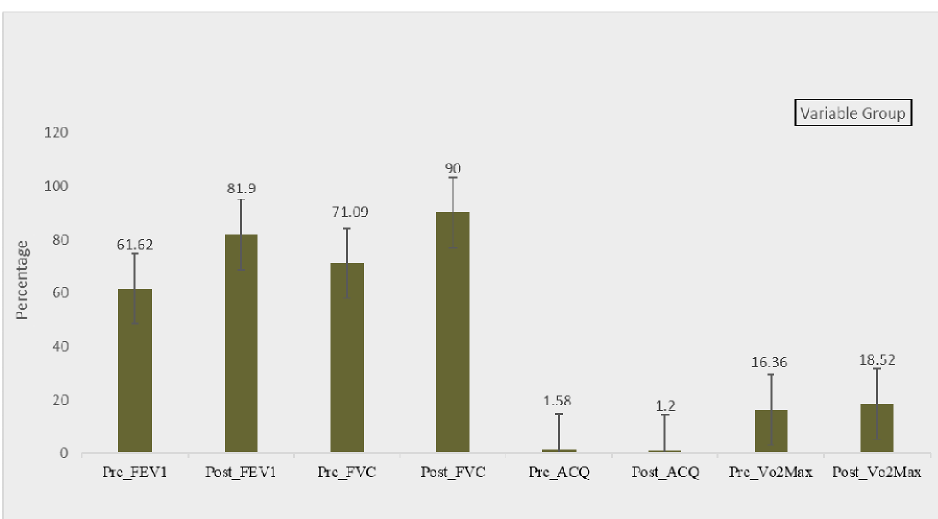

Figure 2. Graph of the average increase and decrease in each measured variable.

Table 2. Test of normality for the overall data.

	Normality test					
Variable	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*P*	Statistic	*df*	*P*
Pre_FEV1	0.110	21	0.200*	0.976	21	0.867
Post_FEV1	0.157	21	0.194	0.967	21	0.663
Pre_FVC	0.175	21	0.091	0.852	21	0.005
Post_FVC	0.160	21	0.169	0.907	21	0.048
Pre_ACQ	0.170	21	0.115	0.957	21	0.462
Post_ACQ	0.151	21	0.200*	0.949	21	0.322
Pre_Vo2Max	0.138	21	0.200*	0.953	21	0.383
Post_Vo2Max	0.476	21	0.000	0.290	21	0.000

Due to the limited number of participants, Table 2 indicates that data in this research is not consistently distributed. Therefore, non-parametric statistical analysis was used and tested with the Wilcoxon signed-rank test.

For this reason, the research performed an inferential test between the pretest and posttest data for all variables: FEV1, FVC, ACQ, and VO2Max. Having statistically analyzed using the Wilcoxon signed-rank test, the posttest mean rank results yielded $P < 0.05$. This value implies combining CR, CT, and HIIT exercises significantly improves lung function, asthma control, and VO2Max. Details of the calculation are illustrated in Table 3.

Table 3. Results of the Wilcoxon Signed Rank Test for Pretest and Posttest Differences.

Variable	Total	P-Value	Z
Post_FEV1 - Pre_FEV1	20	0.000	-3.983[b]
Post_FVC - Pre_FVC	20	0.000	-3.984[b]
Post_ACQ - Pre_ACQ	20	0.000	-4.017[c]
Post_Vo2Max - Pre_Vo2Max	20	0.001	-3.316[c]

Information: b: based on positive ranks. c: based on negative ranks.

Discussion

The study's results indicated that measured variables between the pretest and posttest for all participants experienced both decreases and increases, specifically in FEV1, FVC, ACQ, and Vo2Max. This has been verified with the assistance of the CR, CT, and HIIT exercise programs implemented over 12 weeks. The results indicate significant changes in each measured variable between pretest and posttest.

This study confirms previous research indicating that HIIT has a positive impact on asthma control and reduces the recurrence rate (Martin-Smith et al., 2020; Sawyer et al., 2020). Previous research on Continuous Running (CR) and Chest Training (CT) has also been confirmed to enhance the quality of life for asthma patients by improving respiratory capacity (Kuder et al., 2021). Recent research results have contributed to the literature by suggesting that high-intensity exercise, specifically HIIT, is an effective method for asthma management. This approach has been underutilized in adolescents (Winn et al., 2019) and adults (Toennesen et al., 2018) despite proving to be an effective tool for improving peak aerobic fitness and preventing BMI increase in adolescents, irrespective of asthma. This study explores the increase in intracellular levels, allowing aquaporins and bronchial epithelial cells to contract, thereby raising intracellular ion concentration and mediating inflammation from mast cells, eosinophils, neutrophils, and other inflammatory responses (Rahman et al., 2018).

While exercise is a significant trigger for asthma exacerbation, it can also contribute to the healing of patients (Winn et al., 2021). Physiologically, an increase in intracellular levels through exercise allows the airways, aquaporins, and bronchial epithelial cells to contract, enhancing intracellular ion concentration and mediating inflammation from mast cells, eosinophils, neutrophils, and other inflammatory responses (Balyi, Istvan; Way, Richard; Higgs, 2013; Bompa & Buzzichelli, 2015; Ekblom et al., 2018). Engaging in regular and frequent aerobic exercise, with adequate intensity, brings the same physiological benefits to asthma and non-asthma individuals, with an additional value for asthma patients. This may be attributed to the increased efficiency of the respiratory system, characterized by reduced lung ventilation for general workload, increased maximal breathing capacity, decreased residual air volume due to reduced trapped air, and a more efficient lung ventilation pattern (Hamasaki, 2020; Tomisa et al., 2019). This implies that aerobically trained asthma patients (with good VO2Max) have better capabilities than untrained individuals and exhibit mild or moderate airway obstruction. This research also indicates that improved aerobic fitness increases asthma tolerance and threshold levels, leading to asthma occurrences only during more strenuous physical activities and reducing the need for medication. Improved aerobic fitness also benefits psychological and sociological aspects by boosting confidence, fostering better acceptance, and gaining greater recognition from peer groups and parents, helping to eliminate the negative stigma associated with asthma.

Exercise is beneficial for automatically expanding the respiratory passages. Hence, despite being one of the triggers for asthma exacerbation, exercise is recommended for asthma patients (Bush, 2019; Hamasaki, 2020; Prossegger et al., 2019). Exercise is highly recommended for individuals with asthma. In case of an exacerbation, asthma patients should anticipate, for example, by preparing asthma anticipation equipment such as portable oxygen tanks (oxyfit, oximeter, and inhaler).

Conclusions

The research significantly contributes to the field of asthma management by establishing the efficacy of combination Continuous Run (CR), Circuit Training (CT), and High-Intensity Interval Training (HIIT) in improving lung function and asthma control. The study provides valuable insights into the practical application of exercise programs as complementary interventions for individuals with asthma. The use of inferential statistical tests, specifically the Wilcoxon signed-rank test, adds statistical rigor to the study. The demonstrated significant differences ($P < 0.05$) in pretest to posttest values for FEV1, FVC, ACQ, and VO2Max within each group further authenticate the effectiveness of the exercise programs. Nevertheless, by demonstrating significant improvements in lung function, asthma control, and VO2Max, the study underscores the potential of CR, CT, and HIIT in promoting holistic fitness among individuals with asthma. This holistic approach aligns with contemporary health paradigms emphasizing the interconnectedness of various physiological parameters.

Additionally, coaches, medical professionals, and researchers can contemplate incorporating the findings of this research into the design of CR, CT, and HIIT exercise programs and menus. Moreover, the results of this study can serve as a reference for the development of similar therapies in asthma management, aiming to improve the quality of life for asthma patients by minimizing the occurrence of relapses. Further research is needed, however, involving a larger number of participants for in-depth investigation.

Conflicts of interest – Authors declare that we have no conflict of interest to declare.
Acknowledgement – We express our deepest gratitude to the LPPM of Padang State University (UNP) for financially supporting this research. We also thank the Chair of the Sports Medicine Laboratory at FIK, the Physical Rehabilitation Research Center, and the Dean of the Faculty of Sports Science in UNP for granting permission to conduct this research.

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