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Original Research

Acute Effects of Exercise at Different Temperatures on Clinical Symptoms and Nasal Blood Flow in Patient with Allergic Rhinitis: A Randomized Crossover Trial

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ABSTRACT

International Journal of Exercise Science 17(3): 779-793, 2024. Allergic rhinitis (AR) affects the nose and is triggered by allergens. However, no research studies have analyzed the acute effect of aerobic exercise at different temperatures in AR patients. This study was to determine the acute effect of aerobic exercise at different temperatures on rhinitis symptoms and nasal blood flow (NBF) in AR patients. Fifteen AR patients aged 18–24 years were randomized in a crossover fashion into two protocols: 60 minutes of aerobic exercise at temperatures of 25 °C and 34 °C. The NBF, rhinitis symptoms, peak nasal inspiratory flow (PNIF), fractional exhaled nitric oxide (FeNO) and oxygen saturation (SpO_2) variables were measured. During exercise at 25°C, a notable reduction was observed in NBF, nasal congestion, and sneezing in comparison to exercising at 34°C ($p < 0.05$). The SpO_2 demonstrated significant decreases at 34°C compared to exercise at 25°C after 30 minutes post exercise. The rhinitis symptom scores and NBF in both exercise at 25°C and 34°C significantly decreased and PNIF increased during and after exercise compared to before exercise ($p < 0.05$). In conclusion, both exercising at 25°C and 34°C can contribute to the alleviation of allergic rhinitis symptoms by decreasing rhinitis symptom and NBF. However, exercising in a room at 25°C exhibits a more significant reduction in nasal blood flow, nasal congestion, and sneezing compared to the 34°C setting.

KEY WORDS: Aerobic exercise, exercise environment, peak nasal inspiratory flow, nasal congestion, fractional exhaled nitric oxide

INTRODUCTION

Allergic rhinitis (AR) impacts the nasal passages and is initiated by allergens, prompting an immune reaction characterized by IgE-mediated hypersensitivity responses. The four common symptoms of AR are watery discharge from the nose, blockage of the nasal passages, itchiness in the nose, and sneezing (5, 27). The prevalence of AR is widespread around the world, with an occurrence rate of 20-30% among adults and up to 40% among children (18). In Thailand, AR is becoming increasingly common among the Thai population, which is having a significant effect on their quality of life (23).

Allergens in the nose are recognized by allergen-specific immunoglobulin E (IgE), which then attach to IgE receptors on mast cells and basophils. This triggers the release of chemical mediators such as histamine, leukotrienes, and cytokines, which can lead to the development of allergic rhinitis symptoms (48, 52). Nasal congestion occurs due to tissue swelling in the nasal cavity, narrowing the nasal passages caused by allergens and immunoglobulin E-mediated reactions, resulting in increased blood vessel permeability and congestion (10). Nasal itching can be caused by tissue damage from immune responses and the elimination of infections. Sneezing is a reflex mechanism that helps remove germs, and a runny nose occurs due to increased mucus production by the nasal mucus glands (3, 51). The symptoms experienced by individuals with allergic rhinitis are related to the blood flow in the nasal cavity. Swelling of the tissues in the nasal septum causes nasal congestion, narrowing the nasal passages and increasing nasal blood flow (NBF), which in turn leads to an increase in rhinitis symptoms (6, 31). Hence, if individuals experiencing allergic rhinitis exhibit decreased levels of inflammatory mediators in nasal secretions, which are responsible for symptoms, alongside a reduction in nasal blood flow within the nasal cavity, this will lead to improved nasal clarity and a decrease in various allergic rhinitis symptoms.

There is a strong correlation between exercise and various health benefits, and it is highly recommended as a means of improving health, boosting the immune system, and preventing or treating a wide range of diseases (34). Previous research has indicated that a single bout of exercise can reduce NBF and nasal resistance, and improve symptoms of AR (33, 34, 38). The mechanisms in which acute exercise enhances nasal rhinitis symptoms may stem from sympathetic activity-induced nasal vasoconstriction, leading to a decrease in the volume of venous sinusoids (49). Furthermore, the improvement is likely associated with acute exercise's ability to alleviate nasal congestion by diminishing blood flow and promoting sinus emptying in the capacitance vessels (37). This effect is significant considering the composition of the nasal mucosa, which includes both resistance and capacitance blood vessels. Research has demonstrated a decrease in nasal resistance with exercise (41). In addition, regular exercise has been shown to enhance the clinical symptoms and cytokine profiles in AR patients (7, 47).

Temperature is known to be an important factor that can exacerbate or alleviate the symptoms of allergic rhinitis. The impact of temperature on allergic rhinitis is complex and multifaceted, with both direct and indirect effects. Previous research has demonstrated that varying temperatures can exert both exacerbating and mitigating effects on allergic rhinitis symptoms. Warm temperatures (42-44°C) can decrease AR symptoms and improve nasal obstruction by decreasing the amount of histamine in nasal discharge in patients with persistent AR (3, 12, 30). This may be related to the inhibition of mediators generated by mast cells, basophils, neutrophils, and eosinophils (15, 50, 22). Heat can suppress the reaction between allergens and mast cells or basophils, stabilizing the nasal mucosa and reducing nasal mucus production and vascular permeability. These effects help alleviate symptoms such as itching, sneezing, and nasal congestion. Steam inhalation has been found to improve nasal congestion in patients with allergic rhinitis (50).

Moreover, previous research has found that cool air can also reduce symptoms of allergic rhinitis. Olsson (32) studied healthy subjects, finding that exposure to cold (6°C) reduced blood flow and nasal patency compared to room temperature (23°C). This highlights the importance of nasal congestion in air conditioning and suggests nasal mucosal blood flow changes are involved in regulating body temperature. In addition, a research report that the decrease in temperature observed in the nasal mucosa following local skin cooling was a result of reduced blood flow (13). There are also research studies indicating that participants experienced noticeably reduced nasal congestion when exposed to cold air temperature (43, 53). In addition, Bailey et al. (2) found that lower temperatures in the nasal cavity led to the opening of nasal passages and increased airflow.

However, some studies have found that both at high temperatures and at low temperatures, it can result in increased symptoms of nasal congestion. Naito et al. (24) reported that the nasal airway resistance markedly increased following nasal hyperthermia and Olsson (32) found that exposure to heat (40°C) increased nasal patency without affecting blood flow. In part of cold temperatures, can cause the nasal passages to constrict, making it harder to breathe and increasing the likelihood of nasal congestion (11, 19, 20). Sano (39) discovered that the average nasal resistance markedly rose when the room temperature dropped from 25°C to 15°C. Therefore, previous research indicates the impact of temperature on nasal symptoms remains inconclusive and primarily focuses on resting conditions.

To our knowledge, no studies to date have compared effect of exercise at different temperatures on nasal symptoms in allergic rhinitis patients. Therefore, the primary aim of the present study was to evaluate the acute effect of aerobic exercise at different temperatures on rhinitis symptoms, NBF, peak nasal inspiratory flow (PNIF), fractional exhaled nitric oxide (FeNO) and oxygen saturation (SpO2) in patient with allergic rhinitis. This study was conducted in Bangkok, Thailand, where the average temperature in Bangkok was found to be around 34 ºC. This study focused on designing exercise programs for two different temperatures: 34 ºC and 25 ºC for represent outdoor and indoor (Fitness) exercise temperature, respectively. We hypothesized that exercise at different temperatures would have different effects on rhinitis symptoms and nasal blood flow in patient with allergic rhinitis.

METHODS

Participants

Fifteen adults with allergic rhinitis, ages 18–24 years old. A priori power analysis with G*Power 3.1.9.2 was performed using a predefined power of 0.8, an alpha level of 0.05. These parameters led to a required sample size of at least 12 participants. To compensate for possible drop-outs, 15 participants were added to the sample. The study recruited participants who had a clinical history of persistent rhinitis, which was characterized by symptoms such as nasal congestion, sneezing, nasal itching, and a rhinorrhea occurring for more than four days per week. These participants also had a positive skin prick test with a wheal diameter of three millimeters or more and had a body mass index ranging between 18.5 and 24.9 kg/m^2. The study excluded individuals with a history of smoking, asthma, chronic rhinosinusitis, hypertension, or cardiovascular disease. The participants were instructed to avoid all dietary supplements and to discontinue common allergy medications such as antihistamines, leukotriene receptor antagonists, and nasal steroids for five days, one week, and two weeks, respectively, prior to the start of the experiment.

All participants gave written informed consent prior to participation in the study. Medical and activity histories were obtained via questionnaires. This study was conducted in complete adherence to the principles outlined in the Helsinki Declaration and the ethical guidelines established by the International Journal of Exercise Science (25). The study protocol was approved by the research ethics review committee for research involving humans at Chulalongkorn University and registered as a clinical trial with clinical trials.gov (study # NCT05870644).

Protocol

This was a randomized crossover trial to investigate the acute effect of aerobic exercise at different temperatures on rhinitis symptoms, NBF, PNIF, FeNO and SpO2 in patients with allergic rhinitis. The participants were randomly assigned to either 60 minutes of exercise by cycle ergometer at moderate intensity (50-60% Heart Rate Reserve; HRR) in room temperature at 25 ºC followed by 34 ºC or 60 minutes of exercise by cycle ergometer at moderate intensity (50-60% HRR) in room temperature at 34 ºC followed by 25 ºC by exercising 1 week apart. The target heart rate, calculated using the formula [Target heart rate = (HRmax — RHR) × exercise intensity% + RHR], where HRmax is calculated as 220 minus age and RHR represents the resting heart rate, was monitored by the researcher using Polar H10 heart rate monitor chest strap to maintain the heart rate within the specified intensity level range. Rhinitis symptoms, NBF, SpO2, HR, and Ratings of perceived exertion (RPE) were measured before, during exercise at 15, 30, and 45 minutes, and after exercise at 60 minutes, (0 min post – immediately after the completion of the bout of exercise), 75 (15 min post) and 90 minutes (30 min post) at each temperature. Moreover, PNIF, and FeNO were measured before and after exercise at 60 minutes, 75 and 90 minutes at each temperature. For PNIF and FeNO testing, participants were only masked during the tests at any given time. The mask was taken on and off during the tests and was not worn throughout the exercise and testing period. This research collected data in a temperature-controlled room using air conditioning at 25 ºC and a heater at 34 ºC, with relative humidity controlled between 40 and 60% at the Exercise physiology laboratory, Faculty of Sports Science, Chulalongkorn University.

Rhinitis Symptom Scores: To evaluate nasal symptoms, the Total Nasal Symptom Score (TNSS) questionnaire was employed. The participants were asked to rate the severity of the persistent symptoms of AR, such as nasal congestion, itching, sneezing, and rhinorrhea, before and after each exercise session. The score was 0 to 3, with 0 being none, 1 being mild, 2 being moderate, and 3 being severe.

NBF: NBF was measured using laser Doppler flowmetry (DRT4 moor equipment, UK). A 1.34-mm-diameter flexible nylon sheath-equipped lateral endoscopic probe was positioned in front of the nose.

PNIF: To measure the PNIF, a PNIF meter (Clement Clark International, model IN-CHECK ORAL, UK) was fastened to an anesthetic mask. The procedure involved the participants wearing masks over their mouths and noses that were turned into a plastic cylinder that allowed air to pass through during inspiration. The participants then tightly compressed their lips while forcing air through their noses. The maximum peak flow was measured on a scale between 30-370 L/min, and the airflow was controlled by a diaphragm inside the cylinder. The test subjects sealed their lips while forcing fully inhaling through their noses while wearing a mask over their mouth and nose.

FeNO: To measure FeNO, a FeNO Monitor from BedFont (UK) was utilized. The participants were instructed to take a deep inhalation for approximately two to three seconds before exhaling gently, a process that typically lasted around 10 seconds. FeNO levels were measured in parts per billion (ppb).

SpO2: A pulse oximeter (AccuMed, USA) was used to measure SpO2 by opening the clip and putting the participant's finger into the rubber cushions of the clip.

Heart rate monitor: To assess heart rate, a chest strap heart rate monitor (Polar H10, Finland) was employed. The researcher moistened the electrode area of the strap, secured it around the participant's chest, and adjusted it to ensure a snug fit.

RPE scale: RPE scale is utilized to indicate the level of intensity a participant perceives during exercise. Participants are prompted to rate their perceived level of exertion on a scale ranging from 0 to 10. (0 = No exertion, at rest, 1 = Very light, 2-3 = Light, 4-5 = Moderate, somewhat hard, 6-7 = High, vigorous, 8-9 = Very hard, and 10 = Maximum effort, highest possible).

Statistical Analysis

The statistical program SPSS version 28 for Windows was used to evaluate the data (IBM SPSS Statistics for Windows, NY, USA). To ascertain whether the data were normally distributed, the Shapiro-Wilk test was applied. A two-way repeated measures analysis of variance was employed to assess HR, NBF, PNIF, and FeNO, followed by a post hoc test using the LSD method, to analyze differences both across various time periods and between different temperatures. The Friedman test was used to examine the rhinitis symptoms scores, SpO2, and RPE over time for each temperature. The Wilcoxon test was used to examine the rhinitis symptoms scores and SpO2 between each temperature. The data were presented as the mean and standard deviation. Statistical difference was set at $p < 0.05$.

RESULTS

There were 15 participants in the research collection (10 males, 5 females) (Figure 1). Most participant were youth. They also exhibited normal BMI and blood pressure levels. The general characteristics data of the participants are presented in Table 1.

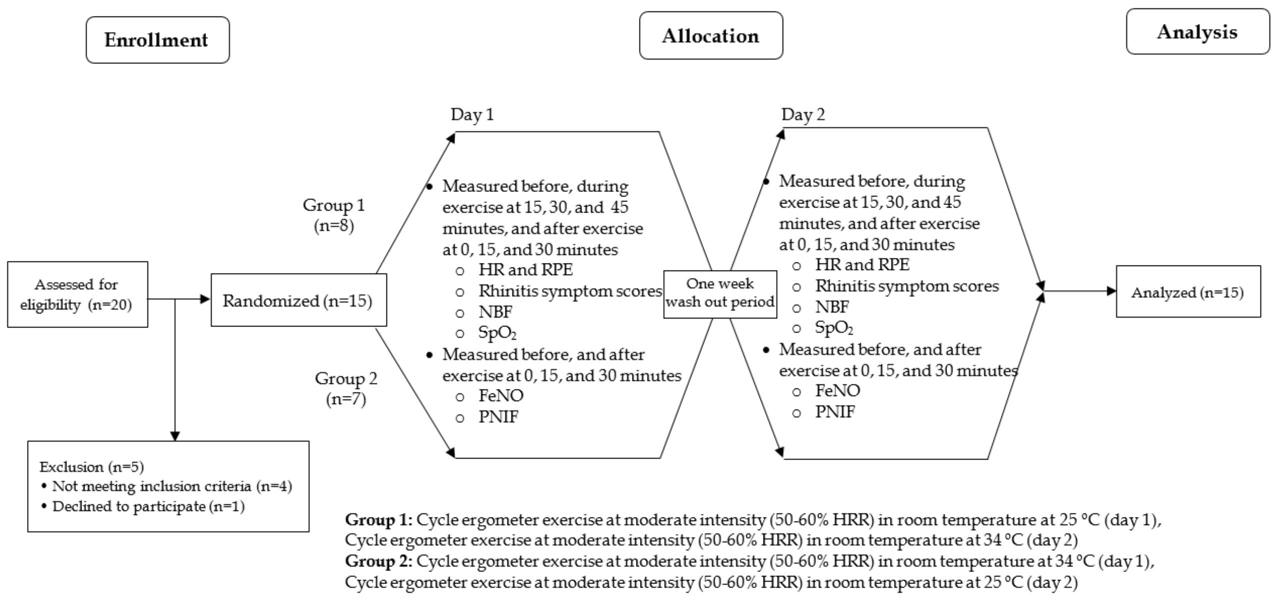


Figure 1. Flow diagram of participant allocation, follow-up and analysis.

Table 1. The general characteristic data.

Variables	AR (n=15)
Age	23.53 ± 4.28
Weight (kg)	64.51 ± 9.86
High (cm)	168.00 ± 7.13
BMI (kg/m^2)	22.78 ± 3.04
RHR (b/min)	81.00 ± 20.82
Systolic BP (mmHg)	116.60 ± 11.84
Diastolic BP (mmHg)	64.20 ± 9.03

BMI = Body mass index, RHR = Resting heart rate, BP = Blood pressure
Data are presented as mean ± SD.

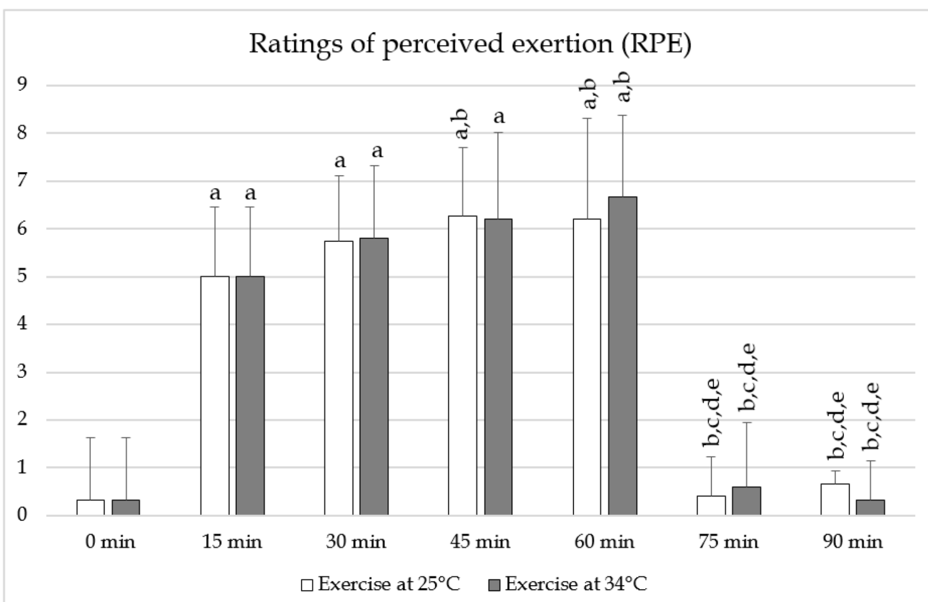
The findings indicated that individuals engaging in exercise at 25°C demonstrated notable reductions in HR (15 and 30 minutes post exercise), nasal congestion (30 minutes post exercise), sneezing (30 and 45 minutes during exercise), and NBF at minutes 15, 30, 45, 60, 75, and 90 compared to those exercising at 34°C. Additionally, SpO2 levels at minute 90 were higher in participants exercising at 25°C than those exercising at 34°C. Further details are provided in the following information.

HR and RPE: The results showed that during exercise, the participants experienced increase in average HR and RPE compared to before exercise in both the 25°C and 34°C environments ($p < 0.05$). Moreover, after 15 and 30 post exercise, there was a significant decrease in HR and RPE compared to during exercise ($p < 0.05$). When comparing temperatures, it was observed that during exercise at 25°C, the subjects exhibited lower heart rates after 15 and 30 post exercise compared to those recorded during exercise at 34°C. The data are shown in Table 2 and Figure 2.

Table 2. The results of the Two-way repeated measures ANOVA for comparing the heart rate variables among before (0 min), during exercise at 15, 30, and 45 minutes and after exercise at 60 minutes (0 min post – immediately after the completion of the bout of exercise), 75 (15 min post) and 90 minutes (30 min post) and between each exercise temperatures.

Temperature	Time (n = 15)							P-Value		
	0 min	15 min	30 min	45 min	60 min	75 min	90 min	Group	Time	Interaction
Heart rate										
Exercise at 25°C	81.00 ± 20.81	140.73 ± 5.43[a]	141.20 ± 7.36[a]	141.80 ± 8.68[a]	141.06 ± 6.13[a]	85.26 ± 15.75[b,c,d,e]	82.80 ± 17.09[a,b,c,d,e]	0.01*	<.001*	0.20
Exercise at 34°C	81.13 ± 12.55	143.46 ± 9.88[a]	142.80 ± 5.84[a]	143.93 ± 6.29[a]	143.40 ± 7.00[a]	91.80 ± 15.40[b,c,d,e]	90.46 ± 15.61[a,b,c,d,e]			
P-value (vs temps)	0.97	0.21	0.40	0.19	0.08	**0.03†**	**0.02†**			

Data are presented as mean ± SD. [a]$p < 0.05$, vs. 0 min, [b]$p < 0.05$, vs. 15 min, [c]$p < 0.05$, vs. 30 min, [d]$p < 0.05$, [e]$p < 0.05$, vs. 60 min, †$p < 0.05$, vs. exercise at 25°C



Data are presented as mean (SD.) [a]$p < 0.05$, vs. 0 min, [b]$p < 0.05$, vs. 15 min, [c]$p < 0.05$, vs. 30 min, [d]$p < 0.05$, vs. 45 min, [e]$p < 0.05$, vs. 60 min, [f]$p < 0.05$, vs. 75 min

Figure 2. The results of the Wilcoxon Signed-Rank test and Friedman test for comparing the Ratings of perceived exertion (RPE) among before (0 min), during exercise at 15, 30, and 45 minutes and after exercise at 60 minutes (0 min post – immediately after the completion of the bout of exercise), 75 (15 min post) and 90 minutes (30 min post) and between each exercise temperatures.

Table 3. The results of the Wilcoxon Signed-Rank test and Friedman test for comparing the rhinitis symptom score variables among before (0 min), during exercise at 15, 30, and 45 minutes and after exercise at 60 minutes (0 min post – immediately after the completion of the bout of exercise), 75 (15 min post) and 90 minutes (30 min post) and between each exercise temperatures.

Temperature	Time (n = 15)							P-Value (vs times)
	0 min	15 min	30 min	45 min	60 min	75 min	90 min	
Nasal congestion scores								
Exercise at 25°C	2.00 ± 0.75	1.53 ± 0.99	0.93 ± 0.70[a]	0.66 ± 0.72[a]	0.20 ± 0.41[a,b]	0.33 ± 0.48[a,b]	0.20 ± 0.41[a,b]	<0.001
Exercise at 34°C	2.20 ± 0.67	1.40 ± 0.73	0.93 ±0.79[a]	0.86 ± 0.74[a]	0.46 0.63[a]	0.40 0.63[a]	0.40 ± 0.50[a]	<0.001
P-value (vs temps)	0.31	0.67	1.00	0.36	0.15	0.73	**<0.001†**	
Itching scores								
Exercise at 25°C	1.80 ± 1.10	0.66 ± 0.90	0.60 ± 0.98[a]	0.46 ± 0.74[a]	0.60 ± 0.98[a,b]	0.33 ± 0.81[a,b]	0.33 ± 0.61[a,b]	<0.001
Exercise at 34°C	0.80 ± 0.86	0.46 ± 0.83	0.53 ± 0.99[a,b]	0.53 ± 0.99[a,b]	0.40 ± 0.73[a,b]	0.46 ± 0.91[a,b]	0.46 ± 0.91[a,b,c]	<0.001
P-value (vs temps)	0.76	1.00	0.58	0.73	0.65	0.15	0.56	
Sneezing scores								
Exercise at 25°C	1.73 ± 0.59	0.66 ± 0.61[a]	0.20 ± 0.56[a]	0.20 ± 0.41[a]	0.06 ± 0.25[a,b]	0.06 ± 0.25[a,b]	0.20 ± 0.41[a]	<0.001
Exercise at 34°C	1.74 ± 0.60	0.66 ± 0.81	0.66 ±0.81	0.33 ± 0.61[a]	0.13 0.35[a,c]	0.20 0.41[a]	0.26 ± 0.45[a]	<0.001
P-value (vs temps)	1.00	0.95	**0.01†**	**0.02†**	0.31	0.15	0.56	
Rhinorrhea scores								
Exercise at 25°C	2.00 ± 0.84	1.20 ± 1.08[a]	0.73 ± 0.96[a]	0.46 ± 0.63[a,b]	0.46 ± 0.51[a]	0.46 ± 0.51 [a]	0.20 ± 0.41[a,b]	<0.001
Exercise at 34°C	2.00 ± 0.75	0.86 ± 0.63[a]	0.60 ±0.63[a]	0.60 ± 0.50[a]	0.33 0.48[a]	0.26 0.45[a,b]	0.40 ± 0.73[a]	<0.001
P-value (vs temps)	1.00	0.37	0.72	0.41	0.31	0.18	0.38	
Total rhinitis symptoms scores								
Exercise at 25°C	7.53 ± 1.06	4.53 ± 1.88	2.53 ± 1.41 [a]	1.80 ± 1.57[a,b]	1.07 ± 1.03[a,b,c]	0.93 ± 0.96[a,b,c]	0.80 ± 1.01[a,b,c,d]	<0.001
Exercise at 34°C	7.54 ± 1.10	4.06 ± 1.43	3.00 ± 2.27[a]	2.40 ± 1.99[a,b]	1.20 ± 1.15[a,b,c,d]	1.07 ± 1.16[a,b,c,d]	1.20 ± 1.32[a,b,c]	<0.001
P-value (vs temps)	1.00	0.68	0.31	0.25	0.41	0.72	0.22	

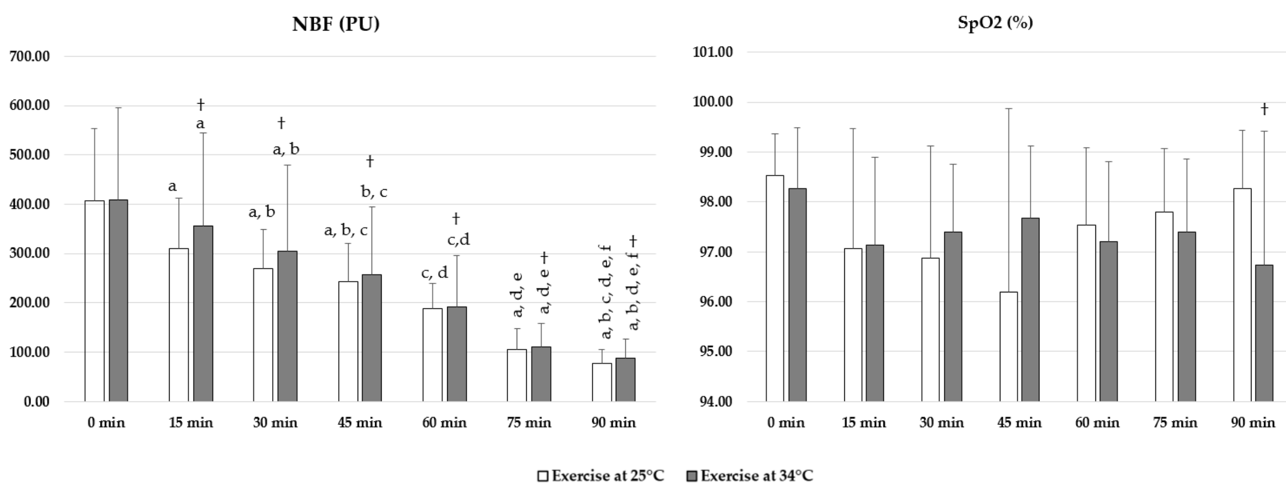
Data are presented as mean ± SD. [a]$p < 0.05$, vs. 0 min, [b]$p < 0.05$, vs. 15 min, [c]$p < 0.05$, vs. 30 min, [d]$p < 0.05$, vs. 45 min, †$p < 0.05$, vs. exercise at 25°C

Rhinitis symptom scores: The symptom scores decrease through time in both exercise at 25°C and 34°C ($p < 0.001$). Furthermore, there was a noteworthy decrease in nasal congestion scores after exercise at 90 minutes (30 min post) ($p < 0.001$) and sneezing scores during exercise at 30 minutes ($p = 0.01$) and 45 minutes ($p = 0.02$) when compared to exercise conducted at 25°C. The data are shown in Table 3.

NBF: NBF alleviation continued after the exercise session ended in both temperatures ($p < 0.001$). Moreover, when exercise at 25°C, there were lower significantly during exercise 15 ($p < 0.001$), 30 ($p < 0.001$), and 45 minutes ($p < 0.001$), after exercise at 60 minutes (0 min post) ($p = 0.009$), 75 (15 min post) ($p = 0.014$), and 90 minutes (30 min post) ($p < 0.001$), than exercise conducted at 34°C. The data are shown in Figure 3.

PNIF: There were significant increases in the PNIF immediately after exercise (at 60 minutes), 15 minutes after exercise (at 75 minutes), and 30 minutes after exercise (at 90 minutes) when compared to before exercise (at 0 minutes) ($p < 0.001$) in both exercises in a room at 25°C and 34°C. However, when comparing the PNIF between exercising in a room at 25°C and 34°C, no difference was found. The corresponding data can be seen in Figure 4.

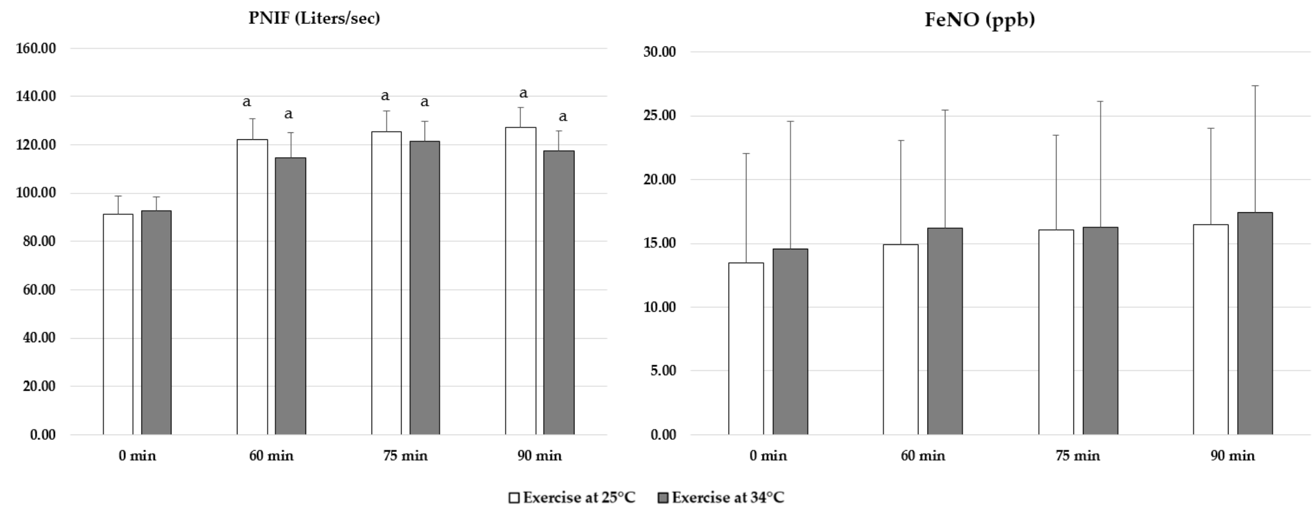
FeNO: The FeNO measurements did not exhibit any significant differences at different time points or between exercising in a room at 25°C and 34°C. The data illustrating this can be found in Figure 4.



Data are presented as mean (SD.) $^{a}p < 0.05$, vs. 0 min, $^{b}p < 0.05$, vs. 15 min, $^{c}p < 0.05$, vs. 30 min, $^{d}p < 0.05$, vs. 45 min, $^{e}p < 0.05$, vs. 60 min, $^{f}p < 0.05$, vs. 75 min,
$^{\dagger}p < 0.05$, vs. exercise at 25°C

Figure 3. The results of the Two-way repeated measures ANOVA for comparing the NBF, and SpO2 variables among before (0 min), during exercise at 15, 30, and 45 minutes and after exercise at 60 minutes (0 min post – immediately after the completion of the bout of exercise), 75 (15 min post) and 90 minutes (30 min post) and between each exercise temperatures.

SpO2: There were no significant differences observed in SpO2 at various time points. However, when comparing the SpO2 during exercise in a room at 25°C and 34°C, the findings indicated that after 30 minutes of exercise (at 90 minutes), the SpO2 demonstrated significant decreases at 34°C compared to exercise at 25°C ($p = 0.008$). Figure 2 provides a visual representation of these results.



Data are presented as mean (SD.) $^{a}p < 0.05$, vs. 0 min

Figure 4. The results of the Two-way repeated measures ANOVA for comparing the PNIF, and FeNO variables among before (0 min), and after exercise at 60 minutes (0 min post – immediately after the completion of the bout of exercise), 75 (15 min post) and 90 minutes (30 min post) and between each exercise temperatures.

DISCUSSION

To our knowledge, this study is the first to investigate the acute effect of aerobic exercise at different temperatures on rhinitis symptoms, NBF, PNIF, FeNO, and SpO2 in patient with allergic rhinitis. The key finding of this study was that engaging in moderate-intensity aerobic exercise using an electric bike in both 25°C and 34°C environments proved to be effective in reducing symptoms associated with an increase in PNIF and a decrease in NBF in individuals with allergic rhinitis.

The research indicated that individuals with allergic rhinitis experienced a distinct rise in HR and RPE immediately after exercise, aligning with the anticipated cardiovascular response during exercise. The autonomic nervous system, influenced by increased metabolic demands and regulatory mechanisms, played a crucial role in this physiological effect. Specifically, the exercise-induced reduction in parasympathetic nervous system activity and heightened activation of the sympathetic nervous system led to an increased heart rate during exercise, consistent with prior study (9).

The present study demonstrated that exercise led to a reduction in rhinitis symptoms such as nasal congestion, itching, sneezing, rhinorrhea, and total rhinitis symptoms in patients with allergic rhinitis. Furthermore, exercise was found to lower NBF while enhancing PNIF. Swelling of nasal tissues, associated with NBF, contributes to congestion (6, 31) and decreases PNIF in allergic rhinitis (46). The alleviation of allergic rhinitis symptoms in individuals following exercise may be attributed to a reduction in NBF and decreased resistance within the nasal cavity. This leads to an increased nasal cavity volume associated with increased PNIF, promoting improved airflow and diminished nasal congestion. Additionally, exercise activates the sympathetic nervous system, causing blood vessel constriction in the nasal cavity and further reducing resistance during exercise (21, 24-25, 48). The current research is consistent with previous studies, which showed a significant decrease in NBF immediately after exercise in allergic rhinitis patient (30, 35, 41, 49). Moreover, studies have indicated that aerobic exercise can help alleviate nasal resistance, contributing to improved nasal clearance (37, 41). In addition, previous study reported that moderate aerobic exercise has an immediate impact on interleukin levels, which in turn decreases inflammatory cytokines associated with allergic rhinitis symptoms (47).

In comparing temperatures, subjects exhibited lower heart rates during exercise at 25°C compared to 34°C. The heightened sympathetic nervous system activity, triggered by the stressors of exercise and heat, releases norepinephrine, stimulating a faster heart rate. This response reflects the body's effort to regulate temperature and ensure sufficient blood flow to vital organs during exercise in a warm environment (17). When comparing variables between exercising in a room at 25°C and 34°C, the findings indicated that, at 25°C, there was a more significant reduction in nasal congestion, sneezing, and NBF compared to exercising at 34°C. The temperature difference between the two conditions played a role in blood vessel constriction. Lower temperatures lead to increased blood vessel constriction, while higher temperatures cause blood vessels to dilate (8). The temperature at 25°C may be attributed to a decrease in NBF. This corresponds with previous studies (10, 32), which found that exposure to cold led to decreased blood flow and nasal patency. The decline in nasal mucosa temperature may resulting from local skin cooling was linked to a reduction in nasal congestion (13) and subsequently leads to a reduction in sneezing. Conversely, at 40°C, NBF remained unchanged while nasal congestion increased.

Our result also showed that after 30 minutes of exercise (at 90 minutes), the SpO2 demonstrated significant decreases at 34°C compared to exercise at 25°C. The SpO2 refers to the quantity of oxygen that is carried and bound to hemoglobin during transportation (14). As body temperature rises, there is a corresponding decrease in blood oxygen levels. Engaging in physical exercise raises body temperature, leading to a reduction in oxygen levels in the blood (1, 14, 16).

In addition, the present study indicated that FeNO no change both exercise in 25°C and 34°C. The findings in line with Scollo et al. (40) indicated that there were no notable variances in FeNO measurements after subjecting participants to a treadmill exercise test. However, several studies have documented that engaging in intense physical activity is linked to a decrease in exhaled nitric oxide (NO) levels (36, 42). FeNO which serves as an indicator of inflammation in the airways, has been found to rise in conditions characterized by airway inflammation. The degree of severity of AR is connected to the levels of FeNO (26, 44).
This research has certain limitations, particularly regarding the exercise location. The size of the temperature-controlled laboratories for hot and cold conditions differed. Although the research maintained relative humidity within the range of 40–60% throughout the testing, specific room

humidity data were not recorded for each sample. Additionally, the sample group consisted of only 15 individuals, with a higher representation of males than females. As a result, caution should be exercised when interpreting our findings. Therefore, further research is needed to investigate the impact of exercise at different temperatures on rhinitis symptoms in a larger sample size and across various types of exercise. Additionally, examining the effects of exercise at 34°C indoors versus outdoors could yield valuable insights. Investigating this aspect during periods of heightened environmental pollution, whether from natural sources like flowers and pollen or man-made factors such as factories and vehicles, would be intriguing. Furthermore, comparing the impact of cold temperatures to warm temperatures in this context would add valuable depth to our understanding.

In summary, participating in exercise at different temperatures proves advantageous for nasal blood flow and alleviating symptoms in those with allergic rhinitis. Both 25°C and 34°C exercise environments can mitigate allergic rhinitis symptoms, but exercising in a room at 25°C exhibits a more significant reduction in nasal blood flow and symptoms compared to the 34°C setting. Opting for a moderate exercise routine is effective in symptom relief, and the choice of temperature should be based on accessibility and appropriateness for the individual. It's important to note that exercising indoors in a climate-controlled environment may be more effective in achieving desired results.

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