Bulletin of Community Engagement
Vol. 6, No. 2, August 2026
https://attractivejournal.com/index.php/bce//index

Efficacy of Diaphragmatic Breathing and Balloon-Blowing Load Exercises in Improving Lung Capacity Among Athlete Runners

Rofi' Nurul 'Aini [1*], Slamet Riyadi [2], Muchsin Doewes [3]
[1,2,3] *Universitas Sebelas Maret, Indonesia*

rofinurulaini256@gmail.com*

ARTICLE INFO
Article history:
Received
January 09, 2026
Revised
June 17, 2026
Accepted
July 11, 2026

Abstract

Lung capacity is an important physiological component that plays a role in the performance of middle- and long-distance runners. Breathing exercises based on strengthening respiratory muscles, such as diaphragmatic breathing and balloon-blowing load exercise have been shown to contribute to improved lung function. This study aims to analyze the effectiveness of DB and BBE in increasing lung capacity in university runners, taking into account differences in age range. The study used a 2×2 factorial experimental design with two types of exercise diaphragmatic breathing and balloon-blowing load exercise and two age categories ≤19 years and >19 years. The study sample was UNS runners selected through a total sampling technique. All participants underwent a four-week training program with a frequency of three times per week and a duration of 30–45 minutes per session. Lung capacity was measured using spirometry in the pre-test and post-test phases. The results showed that both DB and BBE provided a significant increase in lung capacity compared to baseline. BBE showed a greater increase than DB, indicating the effectiveness of expiratory load in training pulmonary ventilation capacity. The findings confirm that a diaphragmatic control-based breathing intervention and expiratory resistance can induce ventilatory adaptations relevant to a young athletic population. Analysis showed that age and training type did not significantly influence pretest and posttest responses, indicating that both intervention models have the potential for relatively universal benefits for young adult runners. Through a structured, 12-session intervention design, this study adds to the evidence that simple, inexpensive, and easy-to-implement breathing exercises can be an effective strategy for supporting athletes' respiratory function. Limitations such as the small sample size, short intervention duration, and the lack of additional mechanistic measurements suggest the need for further research to provide a more comprehensive picture. Overall, this study makes a significant contribution to the literature on respiratory training and confirms the potential of breathing exercises as an important component of a runner's physical capacity development program.

Keywords: Diaphragmatic Breathing, Balloon-Blowing, Lung Capacity, Runners

Published by CV. Creative Tugu Pena
ISSN 2774-7077
Website https://attractivejournal.com/index.php/bce/

INTRODUCTION

Athletics is one of the most fundamental sports in the development of modern sports, encompassing various events such as short-distance, middle-distance, and long-distance running, hurdles, relays, as well as jumping and throwing events (Harbour et al., 2025). The development of athletics at the university level plays a crucial role in fostering long-term achievement, as educational institutions are a primary platform for developing potential athletes. The Athletics Achievement Development of Sebelas Maret University (UNS) is one of the training centers for student athletes who actively compete at the national level. Internal reports indicate a decline in performance over the past two years. Achievement Development Athletics UNS won two bronze medals, two gold medals, and one silver medal at national competitions in 2023. However, in 2024, this achievement dropped drastically to only one bronze medal. According to the coach and teaching assistant, this decline in performance was not only influenced by funding factors and the quality of training, but also the imbalance in performance between athletes, where of the 32 registered runners, only around 10 had the competitive performance to compete at the national level, and only one runner had the potential to compete at the international level.

One crucial factor that emerges in evaluating athlete performance is endurance, particularly in middle- and long-distance runners (Sakamoto et al., 2025). Coaches have noted that UNS runners often experience a decline in performance midway through the race, indicating problems with aerobic capacity and the ability to maintain efficient respiratory ventilation during high-intensity activity. Aerobic endurance itself is closely related to cardiovascular and respiratory efficiency in delivering oxygen to working muscles (Oueslati et al., 2018). At work durations exceeding two minutes, the aerobic energy system becomes dominant, making lung capacity and respiratory effectiveness key factors in athletic performance. Low vital capacity (VC) limits an athlete's ability to maintain maximal oxygen consumption (VO2max), reduces fatigue tolerance, and directly impacts race performance (Dridi et al., 2021).

Observations on UNS athletes indicate variations in lung capacity based on age group. Some athletes under 19 years old had a vital capacity of around 3.3 liters, while athletes over 19 years old averaged a vital capacity of 3 liters. Although the difference appears small, this finding aligns with literature suggesting that lung capacity can decline or not develop optimally after the age of 19–20 years, depending on training factors, body composition, and respiratory adaptations (Kanyhina et al., 2021). These differences in lung capacity across age groups can impact athletes' ability to maintain race rhythm, maximal expiratory capacity, and ventilatory function during high-intensity training (Jun et al., 2016).

Diaphragmatic breathing is a breathing technique that emphasizes the movement of the diaphragm as the primary muscle of respiration, rather than accessory muscles such as the upper intercostal muscles or neck muscles (Ivanyshyn et al., 2024). This technique aims to increase inspiratory depth, increase tidal volume, and improve oxygenation efficiency (Marugán-Rubio et al., 2022). Optimal activation of the diaphragm not only increases inspiratory capacity but also reduces accessory muscle tension, thus conserving energy during running (Braschler et al., 2025). Previous research has shown that diaphragmatic breathing can improve ventilatory efficiency, core stability, and tolerance for moderate-to-high-intensity aerobic activity. Harbour et al., (2025) stated that diaphragm-based breathing exercises help maintain a stable breathing pattern and improve athletes' ability to control their respiratory rhythm under physical and competitive stress. Balloon-blowing exercise is a form of resistance breathing training that targets the expiratory muscles. By applying a load during exhalation through a balloon, this exercise increases expiratory muscle strength, improves forced vital capacity, and increases peak expiratory flow (Bunlam et al., 2024). Balloon-blowing exercise has been shown to increase FVC, FEV1, and peak expiratory flow in college students in their twenties, providing a strong theoretical basis for its potential to improve runners' ventilatory performance. Physiologically, this exercise exerts a pressure overload effect on the expiratory muscles, thereby increasing abdominal and intercostal strength, which play a role in maintaining ventilation during high-intensity exercise.

The findings of this study are important as a basis for developing a more structured, evidence-based training protocol to improve lung capacity and performance in university runners. Effective interventions are expected to help runners increase endurance, improve competitive performance, and reduce the risk of performance decline during competitions. Through these scientific and practical contributions, this research is expected to support efforts to improve athletic performance at the university level and provide a reference for coaches, academics, and sports stakeholders in designing adaptive and personalized breathing exercises.

METHOD

This study used a quasi-experimental design with a 2×2 factorial approach, which combines two types of breathing exercise methods, namely Diaphragmatic Breathing (DB) and Balloon-Blowing Load Exercise (BBE) as well as two age groups of athletes, namely ≤19 years and >19 years. This design was chosen to allow simultaneous analysis of the main effect of each type of exercise and the interaction effect between exercise and age range on lung capacity improvement. The choice of a factorial design also provided greater power in identifying synergistic effects or differences in physiological exercise responses between age groups, as recommended in exercise physiology research that emphasizes interindividual variability in respiratory adaptation.

The study was conducted in the Sebelas Maret University Athletics Achievement Development environment, utilizing the UNS stadium and sports physiology laboratory as measurement locations. Environmental conditions during training and measurement were maintained consistently, including temperature, humidity, and time of day, to minimize physiological bias due to external factors. The entire study lasted four weeks, consisting of a pre-test, intervention, and post-test phases. The four-week period was chosen based on previous findings that respiratory adaptations to breath-bearing exercise can occur from the third to sixth week of a structured training program.

The study subjects were 32 UNS runners actively enrolled in the athletic development program. All subjects were recruited using a total sampling technique, ensuring that all runners who met the inclusion criteria were included in the study. Inclusion criteria included active runners with at least one year of training experience, no history of chronic lung disease such as asthma or acute bronchitis in the past three months, no current injuries that could interfere with their training, and willingness to complete the entire intervention series. Exclusion criteria included missing more than two training sessions, using medications that affect respiratory function, or invalid measurement results due to procedural errors. Before the study began, all subjects received an explanation of the procedure and signed an informed consent form. The study was declared ethically sound by the sports faculty through a research protocol evaluation process in accordance with applicable research ethics standards.

Lung capacity measurements were performed using a standardized digital spirometer that was calibrated before each measurement session. Parameters measured included Vital Capacity (VC), Forced Vital Capacity (FVC), and Forced Expiratory Volume in 1 second (FEV1), as well as the FEV1/FVC ratio as an indicator of expiratory efficiency. The spirometer was chosen because it is the gold standard instrument in evaluating lung function, with a high level of reliability in measuring ventilation parameters. The measurement procedure followed the guidelines of the American Thoracic Society (ATS) and the European Respiratory Society (ERS), including three valid repetitions and selecting the best value for analysis. Other supporting instruments included a stopwatch, an exercise attendance sheet, a subjective respiratory monitoring form, and a uniformly standardized latex balloon for BBE exercises. The balloons used had a similar level of elasticity to ensure consistent resistance load throughout the exercise.

The training program consisted of 12 sessions, three times a week, lasting 30–45 minutes each. Participants performed a light warm-up for 5–10 minutes, then underwent a breathing exercise program tailored to their group. The exercises focused on optimal diaphragm activation with slow, deep breathing techniques in the Diaphragmatic Breathing group. Participants were instructed to lie or sit in a relaxed position, placing one hand on their chest and one on their abdomen to monitor diaphragmatic movement. Inhalation was performed through the nose for 4–5 seconds with abdominal expansion, followed by exhalation through the mouth for 6–8 seconds. The exercises were performed in several sets with a gradual frequency and duration according to the protocol to achieve optimal physiological adaptation of the respiratory muscles. Participants exhaled forcefully into a balloon until it was fully inflated, then released the air in a controlled manner in the Balloon-Blowing Load Exercise group. The exercises were performed in a 90/90 semi-reclined position or sitting upright. The resistance load came from the balloon's internal pressure, which increased as the balloon expanded, increasing the challenge to the expiratory muscles. Each session consists of several repetitions of blowing with rest breaks between sets to prevent excessive respiratory muscle fatigue. Pre-test measurements were taken one day before the first exercise session. Participants were instructed to avoid high-intensity exercise, excessive caffeine consumption, and inhaler use for 12 hours prior to the test. Standard spirometry instructions were provided by the researchers to ensure proper implementation. Post-test measurements were conducted one day after the final exercise session using the same procedure. Comparison of pre-test and post-test values was used to assess changes in lung capacity.

RESULT AND DISCUSSION

Demographic and background characteristics of participants are summarized in Table 1. This includes the distribution of athletes across training types, gender categories, and age. Presenting these characteristics provides a clearer picture of the sample composition and helps contextualize subsequent analyses of physiological responses to the intervention.

Table 1. Demographic Characteristics of Participants (N = 32)

	Category	Frequency (n = 40)	Percentage (%)
Jenis Latihan	Diafragma Breathing	16	50.00
	Ballon Blowing	16	50.00
Gender	Laki-laki	16	50.00
	Perempuan	16	50.00
Usia	≤19 years	17	53.13
	>19 years	15	56.87

The characteristics of the participants in this study showed a relatively balanced distribution across several baseline variables that could potentially influence response to a breathing exercise intervention. Thirty-two university runners participated in the study, with an even distribution of exercise types 16 participants participated in the diaphragmatic breathing protocol and 16 participants participated in the balloon blowing exercise. This balance was important because it minimized baseline bias and ensured that any differences in results were more attributable to the type of intervention rather than to sample distribution factors (Ivanyshyn et al., 2024). The number of male and female participants was also balanced 50% of each in terms of gender. This composition reduced the possibility of gender-based bias in lung functional capacity, given that physiological differences between men and women can affect lung volume, respiratory function, and response to breathing exercises. Participants were grouped into two categories ≤19 years (53.13%) and >19 years (46.87%). Although the numbers in these two groups are not completely balanced, the distribution is still proportional enough to be comparable. This age range is relevant considering that lung capacity tends to increase until around 18–20 years of age before stabilizing or slowing down. Age differences can also affect lung tissue elasticity, respiratory muscle strength, and maximal ventilation capacity (Greiwe et al., 2022). Therefore, the age distribution in this study allows for a more in-depth analysis of the influence of maturation factors on the response to breathing exercises.

Table 2. Lung Function Characteristics

Parameter	Min	Max	Mean Pre	Mean Post	Δ Mean	SD Δ
VC (L)	0.80	8.23	3.88	4.28	0.40	-0.23
VT (L)	0.21	1.74	0.84	1.04	0.20	0.13
IRV (L)	0.35	5.92	2.23	2.20	-0.03	-0.32
ERV (L)	0.06	2.10	0.79	1.03	0.23	-0.01

The descriptive profile of lung function showed considerable variation between individuals. The Vital Capacity (VC) variable ranged from 0.80 L to 8.23 L, indicating heterogeneity in lung functional capacity among runners. Similarly, other components, such as Tidal Volume (VT), Inspiratory Reserve Volume (IRV), and Expiratory Reserve Volume (ERV), also showed varying minimum and maximum values. This variability can be influenced by differences in age, height, gender, fitness level, and previous history of breathing exercises (Shaari et al., 2019). The mean pre-test and post-test values provide a general overview of overall changes in lung function after the intervention.

The results (Table 2) showed an increase in the average VC from 3.88 L in the pre-test to 4.28 L in the post-test, with a Δ mean of +0.40 L. This increase indicates that breathing exercise interventions, both diaphragmatic breathing and balloon blowing, are generally able to increase the vital capacity of the athlete's lungs. The increased VC reflects the improved ability of the lungs to hold maximum air after full inspiration and expiration (Marugán-rubio et al., 2021). This increase most likely comes from adaptations in the respiratory muscles, especially the diaphragm and intercostal muscles, which become stronger after training (Mosley et al., 2024). Diaphragmatic breathing exercises improve deep breathing patterns that optimally activate the diaphragm, while balloon blowing provides expiratory resistance that directly strengthens the expiratory muscles (Deliceoğlu et al., 2024). This mechanical adaptation is then reflected in the increase in VC.

VT also increased from 0.84 L to 1.04 L, with a mean Δ of +0.20 L. This increase indicates that runners are able to inhale and exhale larger volumes of air during normal breathing. Increased VT is an important indicator of resting ventilation efficiency, where the body can conserve energy by increasing the depth of breaths rather than their frequency. Breathing exercises such as diaphragmatic breathing improve the ability to relax accessory muscles, resulting in more efficient breathing. With this technique, athletes can reduce the workload of the respiratory system while running, thus optimizing oxygen use (Kolnes et al., 2019). Balloon blowing provides a resistive stimulus that trains respiratory control and lengthens the expiratory phase, which can also improve control over tidal volume.

IRV actually showed a slight decrease from 2.23 L to 2.20 L, with a mean Δ of –0.03 L. This small decrease may be considered clinically insignificant. This phenomenon can be explained by an increase in VT. When VT increases, some of the inspiratory space previously included in IRV is "used." This means that the body diverts some of the inspiratory reserve capacity to normal breath volume (Kolnes et al., 2024). Therefore, a decrease in IRV does not necessarily indicate a decrease in inspiratory capacity, but rather represents a redistribution of the breathing pattern to become more efficient. IRV is strongly influenced by the ability to maximally expand the thoracic cavity. If the participant is not accustomed to maximally inspiratory with correct technique during the measurement, the IRV may appear stable or slightly decreasing despite the increase in total capacity.

ERV increased significantly from 0.79 L to 1.03 L, with a mean Δ of +0.23 L. This increase is closely related to balloon-blowing exercises, which provide resistance during the expiratory phase, thereby activating the abdominal muscles and intercostal muscles. This exercise physiologically stimulates increased expiratory muscle strength and improves the ability to maximally expel air from the lungs (Sikora et al., 2024). Stronger expiratory ability plays a key role in accelerating gas exchange during high-intensity activity. With increased ERV, athletes have a better capacity to regulate ventilation when facing fatigue during a race.

Effect of Exercise Type and Age Group on Lung Function

Analysis was conducted to evaluate the influence of two main factors, namely the type of diaphragmatic breathing vs balloon blowing exercise and age group.≤19 years and >19 years, and their interaction on lung function parameters in both the pretest and posttest phases. The results of this analysis provide a more in-depth understanding of which variables truly contribute to differences in lung capacity between individuals before and after the intervention.

Table 3. Effect of training type and age (Pretest)

Source	**df**	**SS**	**MS**	**F**	**p-value**
Age group	5	1.770	0.354	2.351	0.073
Training type	1	0.083	0.083	0.551	0.465
Age × Training type	2	0.387	0.194	1.286	0.296
R^2 = 0.362; Adjusted R^2 = 0.141					

The results (Table 3) showed that age group factors tended to influence differences in lung function values, with an F value of 2.351 and p = 0.073. Although this p value has not reached the conventional level of statistical significance ($p < 0.05$), the trend-level significance remains relevant for scientific consideration. A p value approaching 0.05 indicates that variations in lung capacity at baseline can be partially explained by age differences. This is consistent with the respiratory physiology literature, which shows that lung capacity develops with growth until late adolescence, then tends to fluctuate more steadily after entering young adulthood. At ages >19 years, alveolar growth no longer shows a significant increase, so total vital capacity usually remains stable. Conversely, at ages 17–19 years, most individuals are still in the developmental phase of the respiratory system, resulting in higher variations in lung capacity. The type of exercise did not significantly influence lung function scores in the pretest (F = 0.551; p = 0.465). This is reasonable considering that the pretest was conducted before the intervention, so both exercise groups had relatively homogeneous baseline conditions. The absence of significant differences confirms that the randomization of group assignments successfully created a balanced baseline. With an equal baseline, the intervention effect can be more validly interpreted in the posttest phase. The interaction between age group and exercise type, also showed no significant effect (F = 1.286; p = 0.296). This means that before the intervention began, there was no tendency for certain age groups to have higher or lower lung capacity depending on the type of exercise they received. There was no natural bias or matching of age categories to certain exercise types at baseline. The R^2 value = 0.362 and Adjusted R^2 = 0.141 indicate that the pretest model is able to explain about 36.2% of the total variation in the data, but after correction for the number of predictors, only 14.1% of the variation is truly explained by the combination of age, type of exercise, and their interaction. This figure is considered moderate, indicating that baseline lung function is influenced by many other factors outside of these two variables, such as height, respiratory muscle mass, aerobic exercise habits, history of respiratory disease, and genetic variations.

Table 4. Effect of training type and age (Posttest)

Source	df	SS	MS	F	p-value
Age group	5	11.469	2.294	1.290	0.302
Training type	1	1.811	1.811	1.018	0.323
Age × Training type	2	1.186	0.593	0.333	0.720
R^2 = 0.353; Adjusted R^2 = 0.129					

The results in the posttest phase (Table 4) provide important insights into the effectiveness of both breathing exercise programs and how age might influence response to the intervention. Age group remained insignificant on lung function scores at posttest ($F = 1.290$; $p = 0.302$). This lack of significance indicates that after the intervention, age differences were no longer a determining factor for the variations in lung capacity that emerged. This can be interpreted as meaning that the breathing exercise programs had relatively similar, homogeneous effects across both age groups. Breathing exercises such as diaphragmatic breathing and balloon blowing are known to provide universal physiological adaptations to the inspiratory and expiratory muscles, so age differences within a narrow range (17–23 years) are not large enough to produce significantly different adaptive responses. The training type also did not significantly influence posttest results ($F = 1.018$; $p = 0.323$). This finding suggests that, in general, both diaphragmatic breathing and balloon blowing have relatively equivalent effects in increasing or changing lung capacity. Both exercises have different but equally effective adaptation mechanisms; diaphragmatic breathing increases inspiratory efficiency, while balloon blowing strengthens expiratory muscles through resistance. When both exercises are administered for the same duration, the resulting respiratory adaptations may produce comparable improvements, resulting in no statistically significant differences between the two groups. The age × exercise type interaction was also not significant at posttest ($F = 0.333$; $p = 0.720$). The absence of this interaction suggests that exercise type does not provide greater benefits for any particular age group. Both participants aged≤Both 19 and >19 years old showed a homogeneous response to both types of exercise. This strengthens the interpretation that the breathing exercises in this study were not age-specific, at least in the 17 age range.–23 years old is the typical age range for college athletes. The R^2 value of 0.353 and Adjusted R^2 of 0.129 in the posttest indicated that the model was able to explain approximately 35.3% of the variation in the results. After correction for predictors, only approximately 12.9% was actually explained by the three factors in the model. This is similar to the pretest phase, indicating that although age and type of exercise contribute, individual variability remains the primary determinant.

Comparison lung capacity

Analysis was conducted to evaluate the effectiveness of an exercise intervention involving diaphragmatic breathing and balloon-blowing load exercise in improving lung capacity in university runners. The four main lung capacity parameters analyzed were Vital Capacity (VC), Tidal Volume (VT), Inspiratory Reserve Volume (IRV), and Expiratory Reserve Volume (ERV). Complete results are shown in Table 5.

Table 5. Comparing pre–post lung capacity parameters

Parameter	Mean Pre	Mean Post	Mean Δ	t-value	p-value	95% CI for Δ
VC (L)	3.8816	4.2816	+0.4000	3.12	0.004	0.14 to 0.66
VT (L)	0.8438	1.0472	+0.2034	4.21	<0.001	0.11 to 0.29
IRV (L)	2.2391	2.2034	−0.0357	−0.58	0.566	−0.16 to 0.09
ERV (L)	0.7987	1.0309	+0.2322	3.87	<0.001	0.11 to 0.35

The test results showed a significant increase in VC, with a $\Delta = +0.40$ L, $t = 3.12$, and $p = 0.004$, and a 95% confidence interval ranging from 0.14 to 0.66 L, confirming that the change was not a random occurrence. This increase has important physiological implications, as VC is a key indicator of total lung capacity during maximal inspiration. The increase in VC may be due to the combination of two forms of breathing exercises used in the intervention. Diaphragmatic breathing directly increases diaphragmatic muscle activation, reduces accessory respiratory muscle dominance, and improves chest wall mechanical efficiency. This exercise promotes a slow and deep breathing pattern, which in the medium term can increase maximal inspiratory force. Meanwhile, balloon-blowing provides a resistive expiratory load, forcing the respiratory muscles to work harder. The combination of these two mechanisms can result in increased lung tissue elasticity and improved ventilation-perfusion relations, ultimately increasing maximal ventilatory capacity (VC).

VT showed the most consistent and significant increase among all parameters, with $\Delta = +0.203$ L, $t = 4.21$, and $p < 0.001$, with a 95% CI of 0.11 to 0.29 L. Increased VT indicates respiratory efficiency at rest and during submaximal exercise. Improved VT reflects improved lung capacity per breath cycle. Diaphragmatic breathing exercises promote more even air distribution to the lung bases, while balloon-blowing exercises increase intrathoracic pressure, thereby improving expiratory muscle strength. These adaptations allow for increased ventilation during quiet breathing without muscle fatigue. Improved VT can also be explained by improved neuromuscular coordination of the respiratory muscles. Repeated exercise helps improve proprioception and motor control of the diaphragm, intercostals, and other accessory muscles (Eswaramoorthi et al., 2021a). Improved VT can contribute directly to running efficiency by increasing oxygen uptake per breath cycle, thereby reducing the need for excessive ventilation during physical activity.

IRV showed different results compared to the other parameters, with $\Delta = -0.035$ L, $t = -0.58$, and $p = 0.566$, indicating a non-significant change. The CI range (–0.16 to 0.09) crossing zero indicates insufficient evidence to conclude a significant increase or decrease in IRV. Several factors may explain this phenomenon. First, IRV is a component of lung capacity that is more influenced by maximal inspiratory force and the lung's ability to inflate to near-total capacity. Balloon-blowing exercises predominantly target the expiratory phase, rather than maximal inspiration. Although diaphragmatic breathing targets deep inspiration, the intensity of the exercise may not be sufficient to significantly increase IRV over the study period. University runners tend to have relatively high IRV before the intervention, given their habit of deep breathing during aerobic exercise. A high baseline reduces room for improvement. This is known as the ceiling effect, where individuals with optimal lung function are less likely to show significant increases in maximal inspiratory capacity after mild to moderate interventions (Eswaramoorthi et al., 2021b). Another possibility is a redistribution of lung volume due to increases in VT and ERV. When VT increases, some inspiratory volume can be "taken" from the inspiratory reserve (IRV), so that IRV appears to decrease even though total capacity remains elevated. This is not an indication of functional decline, but rather a normal adjustment resulting from changes in breathing patterns.

ERV showed a significant increase with $\Delta = +0.232$ L, $t = 3.87$, and $p < 0.001$, and a 95% CI between 0.11 and 0.35 L. The increase in ERV indicates an improvement in the ability of the lungs and expiratory muscles to exhale air more efficiently. Balloon-blowing exercises, which are resistive expiratory exercises, play a significant role in this improvement. When blowing up a balloon, participants must generate a sufficiently high positive pressure to inflate the balloon, which trains expiratory muscles such as the abdominal, internal intercostal, and transverse thoracic muscles. The stronger these muscles, the greater the volume of air that can be expelled during the forced expiratory phase, which is reflected in the increase in ERV. An increase in ERV can improve ventilation efficiency during physical activity because the lungs are able to return to functional residual capacity more optimally (Bunlam et al., 2024). This can also reduce the risk of air trapping and improve gas exchange. An increase in ERV can also indicate that the lungs have increased elasticity or compliance. Breathing exercises promote the release of tension in the muscles and connective tissues around the chest wall, potentially facilitating both passive and active expiration processes.

DISCUSSION

The results showed no significant effect of age group or type of exercise on changes in lung capacity, either in the pretest or posttest phase. These results indicate that both interventions had relatively homogeneous effects across age groups within the 17–23 year range. This may be due to the relatively narrow age range, resulting in relatively small differences in physiological development between age groups. Research Dasa et al.[25] showed that age-related differences in lung capacity were more pronounced in the early adolescence to early adulthood age range (13–18 years), while the variations tended to be smaller in the 18–23 year age range. Therefore, it is not surprising that the age group variable in this study did not show a significant main effect. On the other hand, the absence of an interaction between type of exercise and age suggests that both interventions operate through similar adaptation mechanisms and are independent of age differences within the observed range. These findings are consistent with the literature emphasizing that diaphragmatic training and resistance-based expiratory exercises have universal benefits in young adult populations, with no major differences in response between 18–23 year olds.

The results of this study, which showed significant increases in VC and VT, align with Abouzeid et al.[26] findings, which suggest that diaphragmatic breathing improves the mechanical efficiency of ventilation by reducing accessory muscle activity and increasing the use of the diaphragm as the primary muscle of inspiration. The increase in VT of +0.20 L in this study is very similar to the findings of Grzebisz[27] who reported increases in VT between 0.15–0.30 L after 4 weeks of controlled breathing training. Tiller et al.[28] study also found that optimal diaphragmatic activation improved trunk stability and overall respiratory efficiency a mechanism that could explain the increase in VC found in this study. Not all studies have shown similar results. Kirby et al.[29] found that the effects of diaphragmatic breathing exercises on lung capacity tended to vary depending on the intensity and duration of the intervention. Exercises lasting less than 2 weeks did not result in significant increases in VC or FVC. Thus, the increase in lung capacity found in this study is likely due to the relatively long duration of the intervention 12 sessions over 4 weeks which allowed sufficient time for neuromuscular adaptations in the diaphragm muscle to occur. Research by Okrzymowska et al.[30] emphasized that the success of diaphragmatic training is also influenced by the training position. The exercises were performed in a lying or sitting position, which helps reduce gravitational resistance to the inspiratory mechanism and allows the diaphragm to function more optimally. This study supports the finding that a stable training position can improve the effectiveness of diaphragmatic breathing patterns, which may explain the improvements in VT and VC in this study.

Balloon-blowing load exercise (BBE) in this study resulted in significant improvements in expiratory parameters, particularly ERV. These results are consistent with those reported by Dridi et al.[4] who found that balloon-blowing can increase FVC, FEV1, and PEF in college students. The resistance generated by the balloon forces the expiratory muscles to work harder, resulting in adaptations in expiratory muscle strength and endurance.[31] A similar mechanism occurs in EMST (Expiratory Muscle Strength Training), where increased abdominal muscle strength is closely linked to increased maximal expiratory volume.[32] The increase in ERV of +0.23 L in this study was slightly greater than the average increase of 0.10–0.18 L reported in several previous studies. This difference can be explained by two main factors. First, the balloon-blowing intensity in this study used the principle of single full inflation, namely one full blow until the balloon is fully inflated, which creates greater internal pressure and produces stronger expiratory resistance than the partial inflation method. Second, the exercise was performed in a 90/90 semi-recline position, which according to Kanyhina et al.[5] provides a more stable biomechanical condition for simultaneous activation of the abdominal muscles and diaphragm. Thus, adaptation in the expiratory muscles is more optimal and has the potential to result in a greater increase in ERV compared to previous studies.

IRV did not show a significant increase in this study. These results are consistent with the study by Lopes et al.[33] which concluded that increasing IRV can only be achieved through inspiratory training with specific resistance. Diaphragmatic Breathing does not provide an external inspiratory load, and Balloon-Blowing focuses on expiration, thus not stimulating the inspiratory muscles to work beyond their normal capacity. IRV is largely influenced by maximal inspiratory capacity, which only increases when inspiratory muscles such as the diaphragm, external intercostals, and accessory muscles receive additional mechanical load stimulation.[31] The relatively stable IRV findings in this study do not contradict, but rather support the concept that each component of lung capacity requires a specific stimulus. Consistent with this mechanism, recent research suggests the use of devices such as the POWER breathe or Threshold IMT to increase IRV through measured inspiratory resistance.

Based on the discussion, it can be concluded that diaphragmatic breathing exercises are effective in increasing lung capacity in runners. This breathing technique helps maximize the function of the diaphragm muscle, making the inspiration process more efficient and increasing the volume of air entering the lungs. With increased oxygen supply, athletes are able to maintain running performance for longer durations. Balloon-blowing exercises have also been shown to be effective in improving respiratory function in runners (Ida Zubaida et al., 2022). Balloon-blowing exercises strengthen the respiratory muscles, particularly during expiration. Strengthening these respiratory muscles helps athletes better control air exhalation during high-intensity physical activity. Increasing lung capacity through these two training methods has a positive impact on athletes' cardiorespiratory endurance (Prastyo et al., 2017). Runners with better lung capacity tend to optimize oxygen use during training and competitions, significantly reducing fatigue levels. Diaphragmatic breathing exercises provide the additional benefit of increasing the efficiency of breathing patterns. Athletes become more regular in regulating their breathing rhythm while running, allowing the body to work more effectively. A good breathing pattern also helps maintain a stable heart rate and reduces physiological stress during sports activities (Primasoni et al., 2021). Meanwhile, balloon-blowing exercises contribute to increasing vital lung capacity and expiratory muscle strength. The stronger an athlete's respiratory muscles, the greater the body's ability to optimally exchange oxygen and carbon dioxide during aerobic activity (Adi et al., 2023). The combination of diaphragmatic breathing exercises and balloon blowing exercises is considered more effective than using either method alone. These two exercises complement each other because they simultaneously train the inspiration and expiration processes. This allows for more comprehensive lung function improvements in runners. Regular and programmed breathing exercises can lead to positive physiological adaptations in athletes' respiratory systems (Alqorniy & Iwandana, 2025). These adaptations include increased lung elasticity, respiratory muscle efficiency, and the body's ability to utilize oxygen optimally during exercise (Ellyas et al., 2021). In addition to increasing lung capacity, diaphragmatic breathing exercises and balloon blowing can also aid the body's recovery process after exercise. More controlled breathing helps accelerate oxygen distribution to body tissues, thus optimizing energy recovery and reducing fatigue. With increased lung capacity and respiratory endurance, runners' overall performance can improve. Athletes are better able to maintain speed, concentration, and stable performance during competitions and intensive training sessions over longer periods (Prasetya et al., 2020). Therefore, diaphragmatic breathing exercises and balloon blowing exercises can be recommended as part of a supportive training program for runners. Both methods are easy, safe, and effective in increasing lung capacity and supporting athletic performance, especially in sports that require high cardiorespiratory endurance.

CONCLUSION

The findings confirm that a diaphragmatic control-based breathing intervention and expiratory resistance can induce ventilatory adaptations relevant to a young athletic population. Analysis showed that age and training type did not significantly influence pretest and posttest responses, indicating that both intervention models have the potential for relatively universal benefits for young adult runners. Through a structured, 12-session intervention design, this study adds to the evidence that simple, inexpensive, and easy-to-implement breathing exercises can be an effective strategy for supporting athletes' respiratory function. Limitations such as the small sample size, short intervention duration, and the lack of additional mechanistic measurements suggest the need for further research to provide a more comprehensive picture. Overall, this study makes a significant contribution to the literature on respiratory training and confirms the potential of breathing exercises as an important component of a runner's physical capacity development program.

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