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Enhancing Respiratory Muscle Strength and Asthma Control in Children with Asthma: The Impact of Balloon-Breathing Exercise

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ABSTRACT

Background: Asthma represents a substantial public health concern, and exploring non-pharmacological avenues, such as respiratory exercises, is crucial for improving lung function and enhancing asthma control in children.

Aims of the study: This study investigates the effects of balloon-blowing breathing exercise on respiratory muscle strength and asthma control in school-age children diagnosed with asthma.

Method: Thirty children, aged 7 to 12 years, diagnosed with asthma, were allocated into two groups: Sustained Maximal Inspiration Breathing Group (SMG; n = 15) and Balloon-Blowing Breathing Group (BBG; n = 15). Both groups participated in breathing exercises five times a week for eight weeks. Physiological data, respiratory muscle strength, and asthma symptoms were evaluated in Pre- and Post-tests, employing paired t-tests for within-group comparisons and independent t-tests for between-group comparisons, with significance set at $p < .05$.

Results: After eight weeks, no significant differences were observed in physiological data (body weight, resting heart rate, systolic and diastolic blood pressure) between pre-test and post-test or between the two groups. Both BBG and SMG groups exhibited increased Maximal Inspiratory Pressure (MIP) and Maximal Expiratory Pressure (MEP) compared to pre-test ($p < .05$). Moreover, the BBG group displayed significantly higher MEP than the SMG group ($p < .05$). Asthma control scores significantly improved in both groups compared to pre-test ($p < .05$), with no significant differences between the groups.

Conclusion: These findings suggest that eight weeks of balloon-blowing breathing exercise positively impact respiratory muscle strength and asthma control in school-age children with asthma. Balloon blowing exercise emerge as a valuable therapeutic intervention for enhancing respiratory health in this population.

KEYWORDS:
Asthma/School – age children; Balloon – blowing breathing exercise; Sustain maximum inspiration; Respiratory muscle strength

TO CITE THIS ARTICLE:
Bunlam, K., Rojnawee, S., Pojsupap, S., Suksawat, Y., & Tongtako, W. (2024). Enhancing Respiratory Muscle Strength and Asthma Control in Children with Asthma: The Impact of Balloon-Breathing Exercise. *Physical Activity and Health*, 8(1), pp. 10–19. DOI: https://doi.org/10.5334/paah.321

INTRODUCTION

Asthma constitutes a prevalent chronic respiratory ailment among children and stands as a considerable public health challenge (Global Initiative for Asthma, 2020), affecting an estimated 339 million individuals worldwide. The prevalence of asthma in the Asia-Pacific region is noteworthy, with rates of 9.5% and 8.7% among children aged 6–7 years and 13–14 years, respectively. In Thailand, data from the Global Asthma Network during 2017–2018 revealed that asthma's prevalence among children exceeded 10% (The Global Asthma Report, 2018). The repercussions of asthma extend beyond individuals and their families, imposing a substantial financial burden on healthcare systems and governments (Macêdo et al., 2016). This condition adversely impacts the physical, emotional, and social well-being of children (Lozier et al., 2019). Chronic inflammation of the airways characterizes asthma, leading to bronchial hyperresponsiveness and decreased airflow limitation (Manning & Schwartzstein, 2001). Manifestations typically encompass persistent coughing, wheezing, chest tightness, and breathing difficulties, particularly at night, often disrupting sleep (Marcelino et al., 2012).

The respiratory systems of individuals with asthma undergo alterations due to heightened airway resistance (Weiner et al., 1990), potentially reducing respiratory muscle efficiency. Changes like hyperinflation elevate respiratory motor output, intensifying the perception of respiratory muscle exertion and contributing to dyspnea (Manning & Schwartzstein, 2001). Studies indicate that children with asthma exhibit diminished respiratory muscle strength (Marcelino et al., 2012; Neumannova et al., 2017; Neumannova et al., 2014).

Childhood, spanning 7–12 years, is a crucial developmental phase marked by milestones. During this stage, the family environment plays a pivotal role, offering support, supervision, decision-making assistance, and behavioral guidance (Hockenberry & Wilson, 2015). Children with asthma face challenges, restricting activities and hindering social interactions and acceptance within peer groups (Collins et al., 2008). Learning experiences are impeded, with a tendency to prioritize asthma treatment over preventive measures during symptoms (Walker & Reznik, 2014). Individuals with asthma exhibit lower pulmonary function compared to non-asthmatic counterparts (Moeller et al., 2015; Sears, 2007).

Nonpharmacological interventions, such as breathing exercises, play a pivotal role in enhancing asthma control and optimizing lung functions for individuals with respiratory conditions. Various techniques can be employed for breathing practices, encompassing breathing control, diaphragmatic breathing exercises, costal breathing exercises, purse-lip breathing exercises (El-kader, 2011; Lima et al., 2008), and sustained maximal inspiration (Fink & Hess, 2002; Mendes et al., 2019). Asthmatic children in the school-age bracket can seek guidance from healthcare professionals on methods involving maximal breathing and breath-holding. The implementation of breathing exercises has been shown to positively impact lung functions (Agarwal et al., 2017; Saxena & Saxena, 2009) and contribute to the strengthening of respiratory muscles. A prior investigation (Jansang et al., 2016) demonstrated the effectiveness of purse-lip breathing exercises using a windmill toy in enhancing both lung function and respiratory muscle strength.

The balloon-blowing breathing exercise employs balloons to enhance exhalation force during respiratory activities. Lee et al. (2011) discovered that this exercise elevated maximum expiratory volume in healthy non-smokers. Kim and Lee (2012) reported that young adults, engaging in balloon breathing training three times weekly for 8 weeks, witnessed improvements in pulmonary function and peak flow rate. Sreedevi (2015) observed that conducting balloon-blowing breathing exercise ten times a day for three days alleviated breathing difficulties in children with lower respiratory tract infections. Das, Nayak, & Pradhan (2018) found that balloon and bubble blowing influenced the physiological development of children with lower respiratory tract infections. Concurrently, Seo and Cho (2018) demonstrated that a balloon-blowing exercise in a 90/90 bridge position, utilizing a ball for 30 minutes daily, five times weekly over four weeks, led to enhanced pulmonary function.

Nevertheless, the impact of balloon-blowing exercise on asthma control and respiratory muscle strength in individuals with asthma remains unestablished. This research specifically delves into the effects of balloon-blowing exercise on asthma control and respiratory muscle strength in school-age children diagnosed with asthma. Given the simplicity and appropriateness of balloon-blowing exercise for this age group, it is anticipated that the insights garnered from this study will prove advantageous for these children, ultimately enhancing their quality of life.

MATERIALS AND METHODS

STUDY DESIGN AND PROCEDURE

This was a randomized controlled trial; it was registered as a clinical trial on clinical trials.gov (NCT04874649). The study protocol was approved by the Institutional Ethical Review Board of the Royal Thai Army Medical Department, Thailand (IRBRTA 963/2562). 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 24 participants in total (n = 12 in each group). To compensate for possible drop-outs, 15 participants were added to the sample.

Before engaging in the study, all participants and their parents were given written informed consent. Thirty school-age children with asthma aged 7–12 years who visited the outpatient department of Phramongkutklao Hospital, Bangkok, Thailand, were divided into two groups: a sustained maximal inspiration breathing group (SMG, n = 15) and a balloon-blowing breathing group (BBG, n = 15). The inclusion criteria were physician-diagnosed asthma for at least 6 months, and the asthma severity was not greater than level 2 (FEV1 ≥ 80%). Children who participated in another study or had a history of exercise-induced asthma were excluded. All participants were randomly assigned to the SMG or BBG group. They continued to receive their regular medication.

After obtaining approval from their primary healthcare provider to participate, participants underwent a 2-hour orientation, covering training in assessment (including physiological characteristics, respiratory muscle strength testing, and asthma control questionnaires) and intervention procedures (specifically, breathing exercises). Following the initial evaluation, participants were provided with a manual notebook outlining the program, including an exercise log to measure program adherence. Each participant received personalized instructions for a home-based breathing exercise program (to be conducted 5 days per week for 8 weeks), with close monitoring by researchers.

BREATHING EXERCISES

Balloon-blowing breathing

Using a balloon size control device, vital capacity was measured as follows: as much air as possible was inhaled through the nose and exhaled through the mouth quickly and strongly into the balloon; the mouth of the balloon was covered, and its diameter was measured (Figure 1a). We used a round natural rubber latex balloon with a size of 10 inches and fastened a plastic tube with a diameter of 1 cm and length of 5 cm to the mouth of the balloon (Figure 1b).

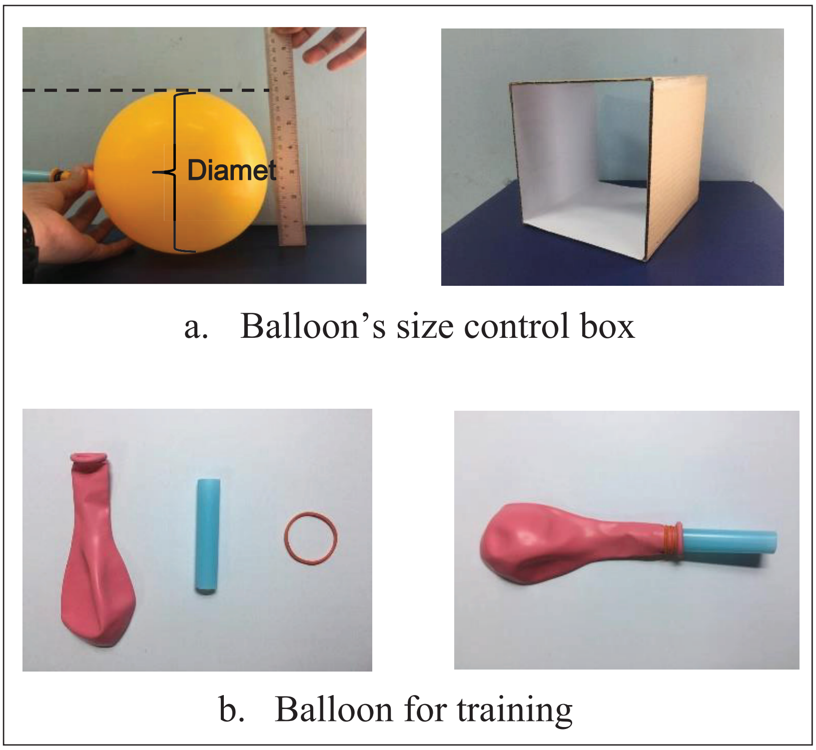

Figure 1 Balloon's size control box **(a.)** and balloon for training **(b.)**.

The participant sat on a chair with the back and head close to the wall, took in a full breath through the nose, held it for 3 seconds, and exhaled it through the mouth fully into the balloon while letting it expand until it touched the size control device. Air was slowly exhaled through the mouth and held for 1 second of exhalation and counted as one breathing cycle. Doing this three times counted as one set. Each exercise was performed for three sets, with 1-minute rests between sets. The participants were asked to practice this for 5 days per week for 8 weeks.

Sustained maximal inspiration breathing

Regularly, medical professionals utilize the practice of sustained maximal inspiration breathing as a standard approach to guide and instruct pediatric asthma patients during their hospital treatment and for them to practice as a self-care routine at home. The procedure involves deeply inhaling and sustaining maximum inspiration for 3 seconds, followed by a gradual exhalation through the mouth and holding the breath out for 1 second. Participants are seated on a chair with their back and head close to the wall. Completing this sequence three times constitutes one set, and each exercise session comprises three sets with one-minute breaks between them.

Participants in both the BBG and SMG groups were directed to engage in practice at home for five days each week over an eight-week duration, specifically on Monday, Tuesday, Thursday, Friday, and Saturday. Parents played a crucial role in supervising and guiding the at-home training. Researchers recommended documenting exercises in a manual. Biweekly follow-up calls with participants and parents, lasting approximately five minutes, involved inquiries about adherence, challenges, symptoms, as well as addressing any issues encountered during sessions. Additionally, there was a reminder for parents to record details in the manual.

EVALUATION OF RESPIRATORY MUSCLE STRENGTH

Respiratory muscle strength was assessed by measuring the maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) expressed in cmH2O using a portable handheld mouth pressure meter (MicroRPM) with a nose clip. The participant was placed in the sitting position, with the hip at a 90° angle and the feet flat on the floor. For the MIP measurement, the participants were asked to exhale until they felt no air remaining in their lungs; this was followed by forceful inhalation. For the MEP measurement, the participants were asked to inhale until their lungs were completely filled with air; this was followed by forceful exhalation. All measurements were conducted within one week after the completion of the eight-week training program.

ASTHMA CONTROL ASSESSMENT

The Childhood Asthma Control Test (C–ACT) was developed to assess childhood asthma control using a self-administered questionnaire with seven items. The C-ACT questionnaire has two parts. The first four items are questions to be answered by children. The last three items are questions to be answered by parents or caregivers. The C-ACT assesses daytime and night-time asthma symptoms, the use of reliever medication, and limitations of daily activities within the previous 4 weeks. The sum of scores for the items is used to determine the level of asthma control: 27 indicates optimal asthma control, 20–26 indicates good control, and ≤19 indicates uncontrolled asthma (Liu et al., 2007).

As shown in Figure 2, the eligible participants were allocated into two groups: SMG (n = 15) and BBG (n = 15). Five participants dropped out from the study because of discontinues intervention and three participants dropped out from the study because of scheduling difficulties. Therefore, the SMG and BBG groups comprised of 15 (Male = 10, Female = 5) and 15 (Male = 10, Female = 5) subjects, respectively.

PHYSIOLOGICAL DATA

Physiological characteristics are shown in Table 1. There were no significant differences in body weight, resting heart rate, and blood pressure.

STATISTICAL ANALYSIS

This study used SPSS Statistics for Windows, Version 17.0 (SPSS Inc., Chicago, IL, USA) for data processing and analysis. All data were statistically analyzed for the normality of their distributions using the Shapiro-Wilk test before calculating the mean and standard deviation (SD).

Physiological data, respiratory muscle strength, and asthma control in the groups were analyzed using independent t-tests. A paired t-test was used to compare the data before and after the breathing exercise. Statistical significance was set at $p < 0.05$.

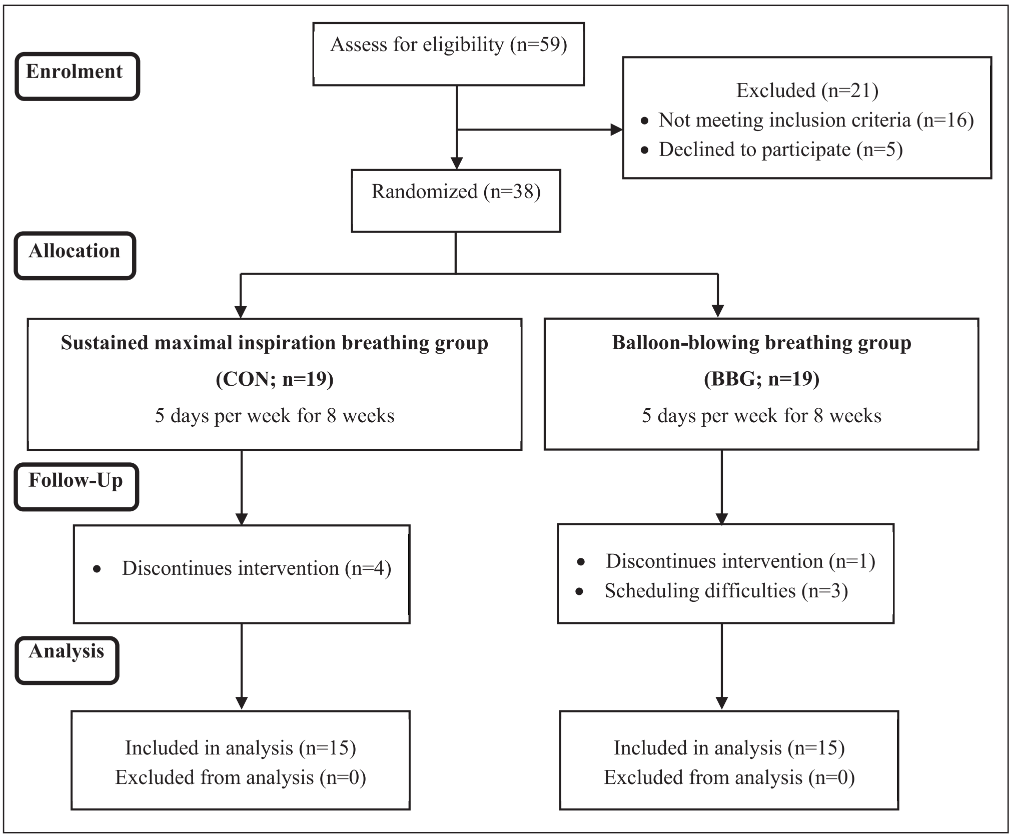

Figure 2 CONSORT 2010 flow diagram of participant allocation, follow-up and analysis.

VARIABLES	SMG (n = 15)	BBG (n = 15)
Weight (kg)	34.51 ± 4.91	38.45 ± 13.82
Resting heart rate (b/min)	93.87 ± 14.18	87.93 ± 13.58
Systolic BP (mmHg)	105.47 ± 17.38	106.40 ± 12.78
Diastolic BP (mmHg)	69.27 ± 9.63	68.27 ± 6.67

Table 1 The physiological characteristics of the SMG and BBG group.

Data are presented as mean ± SD (BP = Blood pressure).

RESULTS

RESPIRATORY MUSCLE STRENGTH

After 8 weeks, the SMG and BBG groups had significantly increased in MIP ($p = 0.006$, $p = 0.000$) and MEP ($p = 0.001$, $p = 0.000$) compared with the pre-test. In addition, MEP was significantly higher in the BBG group (69.40) compared with the SMG group (87.13, $p = 0.000$) (Figure 3).

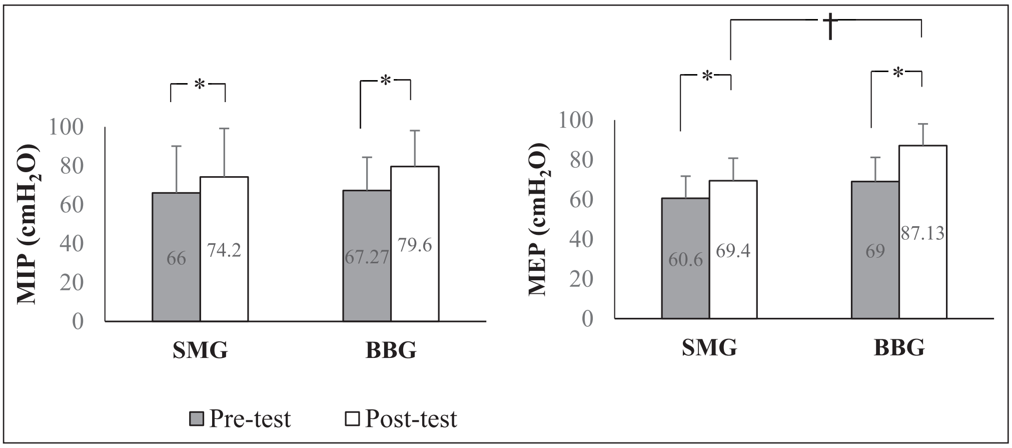

Figure 3 The comparison of the respiratory muscle strength variables between the SMG and BBG group.

Data are presented as mean ± SD. *$p < .05$, vs. pre-test, †$p < .05$, vs. SMG.

DOI: 10.5334/paah.321

ASTHMA CONTROL

The SMG (23.00 ± 2.48 to 25.27 ± 1.75, p = 0.000) and BBG groups (22.93 ± 2.60 to 25.00 ± 1.65, p = 0.000) had significantly increased in the C-ACT scores compared to pre-test. There were no significant differences in the C-ACT scores between the two groups. The results shown in Figure 4.

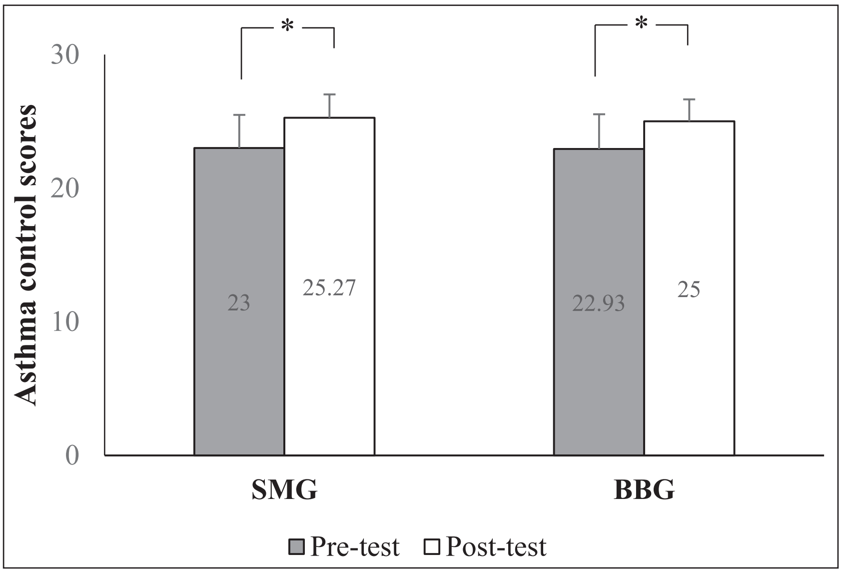

Figure 4 The comparison of the asthma control variables between the SMG and BBG.

Data are presented as mean ± SD. *p < .05, vs. Pre-test.

DISCUSSION

RESPIRATORY MUSCLE STRENGTH

The findings revealed significant alterations in Maximal Inspiratory Pressure (MIP) and Maximal Expiratory Pressure (MEP) following an 8-week regimen of balloon-blowing breathing exercise ($p > .05$). These outcomes align with previous studies, including those conducted by Jun et al. (2016), demonstrating enhanced functions of the rectus abdominis and other respiratory muscles through balloon air-based breathing exercise administered three times weekly for 6 weeks, as evidenced by electrocardiography findings. Importantly, improvements were noted in the primary muscles involved in respiration—the diaphragm muscles and intercostal muscles. This consistency corresponds to investigations into the impact of home-based breathing exercises on respiratory muscle strength in school-age children with chronic obstructive pulmonary disease (Núñez et al., 2014). Another study indicated that daily breathing training for six months increased both MIP and MEP. Additionally, Kang et al. (2016) research showed that 30-minute diaphragmatic breathing exercises, conducted three times a week for 5 weeks, enhanced respiratory muscle function in patients with chronic obstructive pulmonary disease.

In the context of asthma's pathological characteristics, heightened airway resistance in asthmatic patients may lead to airway obstruction, potentially improving lung function and respiratory muscle performance. This observation is rooted in the presence of residual air in the lungs (hyperinflation), complicating the breathing process. The loss of elastic recoil in the lungs negatively impacts respiratory muscle performance, especially the diaphragm muscles, hindering their complete expansion and resulting in decreased MIP and MEP (Gold & Koth, 2015). MEP serves as an indicator of the contractile capacity of respiratory muscles, measured by the maximum expiratory pressure and expiratory pressure. MIP reflects the strength of the diaphragm muscles, while MEP indicates the strength of the abdominal and intercostal muscles during normal exhalation (Gomieiro et al., 2011)—an inherently passive process facilitated by the natural relaxation of the diaphragm and intercostal muscles. However, when forced exhalation occurs, the abdominal muscles, including the rectus abdominis and transverse abdominal muscles, contract.

The balloon breathing exercise entails forceful air-blowing into the balloon. As the balloon inflates, its elastic force and resistance increase, particularly in the abdominal muscles. This intensified resistance prompts increased engagement of the muscles involved in exhalation and the abdominal muscles (Kim & Lee, 2012). Consequently, balloon breathing exercise enhances the strengths of respiratory muscles for exhalation and abdominal muscles. This, in turn, results in heightened inhalation and exhalation pressures, reducing airway obstruction and enhancing airflow in asthmatic patients due to the increased strength and endurance of respiratory muscles.

The MEP demonstrated a significantly higher level in the balloon-blowing group compared to the SMG group. The balloon-blowing exercise involves a process where inhalation and air-holding are followed by exhalation against the resistance offered by the balloon. When air is blown into the balloon, force is applied during exhalation, and the resistance of the balloon increases as it enlarges. This heightened resistance intensifies the engagement of both the breathing and abdominal muscles (Kim & Lee, 2012), but within the constraints of maximum breath. This training specifically targets lung expansion and serves as a complementary practice to other breathing exercises that include inhalation, breath-holding, and exhalation but lack resistance. The distinction between the two lies in the exhalation phase, where balloon-blowing exercises necessitate the application of force, while breathing exercises for maximum breath and hold do not demand force. Consequently, balloon-blowing breathing exercises contribute to the strengthening of muscles involved in exhalation.

ASTHMA CONTROL

In our investigation, all participants presented with intermittent symptoms, as diagnosed by a clinician regarding the severity level of asthma. Both the sustained maximum inspiration and balloon-blowing breathing exercise groups exhibited significantly elevated C-ACT scores post-exercises. However, there were no notable differences in the C-ACT scores between these two groups. These findings align with the study conducted by Thomas et al. (2009), where adult asthmatic patients undergoing regular diaphragmatic breathing for 10 minutes daily for 4 weeks, in addition to practical asthma advice, exhibited improved asthma control after a 6-month follow-up compared to the group receiving only practical advice. Similarly, Grammatopoulou et al. (2011) observed increased mean ACT scores in adults with mild asthma who engaged in diaphragmatic breathing exercises for 60 minutes daily, three days a week, for 4 weeks. This was corroborated by Ritz et al. (2014), who found that capnometry-assisted respiratory training and slow breathing exercises conducted twice a week for 5 weeks led to enhanced asthma control in asthmatic patients through a randomized controlled trial. Additionally, Hepworth et al. (2019) reported significant improvement in asthma control scores in asthmatic children following 20 minutes of Buteyko breathing daily for 12 weeks.

Breathing exercises serve as self-management tools for school-age children to prevent asthma symptoms. The aim of these exercises in asthmatic patients is to normalize breathing patterns by increasing movement in abdominal and chest muscles, thereby enhancing airflow, reducing hyperinflation, and improving lung function (Mike & Anne, 2014). Notably, asthmatic school-age children may perceive the ability to improve respiratory muscle strength through these exercises, fostering healthier behaviours. Confidence in their capability to manage their conditions encourages children to adopt positive health behaviours. In this study, school-age children with asthma initiated breathing exercises to adjust their health behaviours. Furthermore, they consistently performed these exercises five days a week for eight consecutive weeks, aligning with the Global Initiative for Asthma (2020), which underscores the effectiveness of self-management in controlling and mitigating asthma severity in pediatric patients.

Assessment of asthma control in children in this study focused on symptoms such as coughing, breathing, and daytime wheezing. When children practice breathing exercises at home, they may benefit from social support provided by their families. Positive family management behaviours are associated with better control of asthmatic symptoms in children (Ungar et al., 2015). It is crucial for children to be informed about changes in their health behaviour, possessing the awareness and capability for self-regulation to effectively control their conditions and enhance their overall health.

This study has limitations, including the constraint that the asthma severity in the sample group was confined to level 2 (FEV1 ≥ 80%). Another limitation pertains to the small sample size, underscoring the need for larger and more diverse participant recruitment in subsequent studies to improve the generalizability of results. This broader participant pool would enhance our understanding of the impacts of breath training with a balloon across different demographics and disease severities. Additionally, the researchers only adjusted the balloon size before the experiment, potentially hindering its optimal expansion for lung capacity development. Acknowledging the potential biases in self-reported measures is crucial, given that reliance on such data may introduce subjectivity and impact result accuracy. To address this, future research could incorporate objective measures or validation methods. For future studies, investigating the long-term effects of this exercise beyond eight weeks would provide valuable insights into the sustainability and durability of the benefits derived from balloon-assisted breath training. Examining the extended impact over time would contribute to a more thorough understanding of the potential therapeutic value of this intervention.

CONCLUSION

Balloon-blowing breathing exercise five times per week for 8 weeks was effective for respiratory muscle strength in school-age children with asthma. In addition to helping to control asthma better, balloon-blowing breathing exercise requires force to counteract the resistance of the balloon during inflation, which has a better effect on the strength of the exhaled muscles than other exercises indicated by a higher MEP. The balloon-blowing breathing exercise is an easy and fun alternative breathing exercise that can be effective for pediatric asthmatic patients.

DATA ACCESSIBILITY STATEMENT

The data supporting the findings of the current study are available from the corresponding author on reasonable request.

ACKNOWLEDGEMENTS

We are indebted to all volunteers. Thanks also go to all the nurses in Specialty Cline Pulmonary-Allergy & Immunology and Respiratory and Critical Care Division, Phramongkutklao hospital, Bangkok, who provided place for collecting data. This study was supported by Graduate School Fund, Faculty of Sports Science Fund, and Exercise Physiology in Special Population Research Unit, Ratchadapisek Somphote Endowment Fun, Chulalongkorn University.

COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

K.B. designed and performed the experiments, data collection, and analyzed the data. S.R. designed and performed the experiments, and aided in interpreting the results and discussion, revise/review the manuscript. S.P. and Y.S. contributed to sample preparation. W.T. conceptualized and designed the study, assisted with the implemented of the intervention, data collection, interpreting the results, discussion, and conclusion, draft and revise/review the manuscript. All authors have read and approved the manuscript and gave consent to publish it.

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TO CITE THIS ARTICLE:
Bunlam, K., Rojnawee, S., Pojsupap, S., Suksawat, Y., & Tongtako, W. (2024). Enhancing Respiratory Muscle Strength and Asthma Control in Children with Asthma: The Impact of Balloon-Breathing Exercise. *Physical Activity and Health*, 8(1), pp. 10–19. DOI: https://doi.org/10.5334/paah.321

Submitted: 24 November 2023
Accepted: 20 January 2024
Published: 09 February 2024

Physical Activity and Health is a peer-reviewed open access journal published by Ubiquity Press.