

Contributory effects of resistance and respiratory muscle training on anaerobic threshold and peak power output in collegiate women athletes

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Abstract

Optimizing athletic performance depends on evidence-based strategies that enhance both physiological efficiency and physical output. Although resistance training (RT) and respiratory muscle training (RMT) independently improve athletic capacity, few studies have examined their combined effects, particularly among collegiate women athletes, who remain underrepresented in exercise science research. Guided by Selye's Adaptation Theory and the Specificity Principle, this study investigated the effects of an integrated RT and RMT program on anaerobic threshold and peak power output in collegiate female athletes. A single-group, quasi-experimental, longitudinal pretest–posttest design was used. Seven collegiate women athletes (aged 18–25 years) completed a five-week combined intervention consisting of progressive resistance exercises (squats, lunges, planks) and incentive spirometry-based inspiratory muscle training, conducted twice weekly. Anaerobic threshold was examined via the 300-yard shuttle run test, while peak power output was measured using the vertical jump test. Pretest and post-test data were examined using descriptive statistics and paired-sample t-tests ($\alpha=0.05$). Participants showed a statistically significant improvement in anaerobic threshold, with mean 300-yard shuttle run completion times decreasing from 96.14 ± 26.17 seconds at pretest to 73.37 ± 5.12 seconds at post-test ($t=2.688, p=0.036$). Conversely, peak power output showed no statistically significant change, with vertical jump height increasing marginally from a pretest mean of 38.14 ± 3.18 cm to a post-test mean of 38.71 ± 2.50 cm ($t=0.573, p=0.587$). These data suggest that a five-week combined RT and RMT program enhances anaerobic capacity and fatigue tolerance in collegiate women athletes, likely by improving ventilatory efficiency and delaying the respiratory muscle metaboreflex. However, five weeks of integrated training is insufficient to produce significant neuromuscular adaptations for maximal explosive power. Conditioning coaches should incorporate RMT to build anaerobic endurance, but combine it with longer-duration (≥ 8 weeks) power-specific modalities (e.g., plyometrics) to optimize peak power production.

Keywords: resistance training, respiratory muscle training, anaerobic threshold, peak power output, collegiate women athletes

Introduction

Optimizing athletic performance requires structured and evidence-based training strategies that enhance physiological efficiency and measurable performance outcomes. In competitive sports, particularly at the collegiate level, athletes are required to perform repeated high-intensity efforts that demand both muscular power and efficient energy utilization. Two key physiological indicators associated with such performance are anaerobic threshold and peak power output. Anaerobic threshold reflects the highest exercise intensity at which the body can maintain a balance between lactate production and removal, while peak power output represents the maximum mechanical power produced during explosive movements such as sprinting or jumping. Improvements in these physiological markers are associated with enhanced athletic capacity, delayed fatigue, and improved competitive performance.

Resistance training has consistently been recognized as an effective intervention for improving muscular strength, neuromuscular coordination, and power production. Recent research confirms that progressive resistance training improves neuromuscular efficiency, muscle fiber recruitment, and explosive power, all of which contribute to enhanced athletic performance (Hughes et al., 2023; Rathi et al., 2023; Zouita et al., 2023). For collegiate athletes, resistance training plays a crucial role in developing strength and power capacities required for high-intensity sports performance.

At the current level of knowledge, the performance benefits of resistance training are well established. In a meta-analysis of youth athletes, Lesinski et al. (2016) showed that resistance training improves muscle strength as well as vertical jump, sprint, and agility performance, and that the size of these gains follows a dose-response relationship governed by training period, frequency, and intensity. In female athletes specifically, resistance training improves muscular fitness and muscle morphology (Zouita et al., 2023) and transfers to sprint performance in team-sport athletes (Hughes et al., 2023; Rathi et al., 2023). However, most of these programs lasted eight weeks or longer and relied on external loads and specialized equipment, which leaves open the

question of what shorter, low-equipment programs, more typical of resource-limited collegiate settings, can realistically achieve.

In addition to muscular conditioning, respiratory efficiency plays a critical role in sustaining high-intensity exercise. During strenuous physical activity, respiratory muscles must work efficiently to supply oxygen to active muscles while removing metabolic by-products such as carbon dioxide. Respiratory Muscle Training (RMT) has emerged as a specialized conditioning approach designed to strengthen inspiratory and expiratory muscles, improve ventilatory efficiency, and delay respiratory fatigue (Shei, 2018). Recent studies have demonstrated that RMT can enhance exercise tolerance, improve endurance performance, and delay the onset of fatigue among athletes (Chang et al., 2021; Fernandez-Lazaro et al., 2022; Xavier et al., 2025). Strengthening respiratory muscles may therefore improve oxygen delivery and reduce the physiological strain associated with intense exercise.

The evidence base for RMT has also expanded considerably. Early syntheses concluded that RMT improves performance in athletes (HajGhanbari et al., 2013) and that it enhances endurance performance in healthy individuals, with the largest benefits observed in less-fit individuals and in longer-duration events (Illi et al., 2012). Later trials and reviews extended these findings to soccer (Ozmen et al., 2017; León-Morillas et al., 2021), wrestling (Tosun et al., 2025), taekwondo (Koç & Sarıtaş, 2019), short-track speed skating (Kowalski et al., 2024), and para-sport (Akıncı et al., 2024), and even acute respiratory warm-up protocols have been associated with higher anaerobic power output (Özdal et al., 2016). Meta-analyses further indicate that inspiratory muscle training with linear-workload devices improves sports performance and cardiopulmonary function (Karsten et al., 2018; Fernandez-Lazaro et al., 2022). Nevertheless, these reviews note substantial variability in devices, training loads, and outcome measures (Akıncı et al., 2024), and a recent review of team sports concluded that effective protocols for intermittent performance typically used threshold loading for six to eight weeks at a high weekly frequency (Kowalski et al., 2025). Much less is known about lower-dose, low-cost approaches and anaerobic, repeated-sprint outcomes compared with aerobic endurance.

The physiological rationale for RMT in high-intensity sport rests largely on the respiratory muscle metaboreflex. During heavy exercise, fatiguing respiratory muscles trigger a sympathetically mediated vasoconstriction that diverts blood flow away from the locomotor muscles, accelerating limb fatigue and limiting performance (Subramanian & Goyal, 2025). Inspiratory muscle training may attenuate this reflex. In a randomized sham-controlled trial with professional women football players, Archiza et al. (2018) found that six weeks of inspiratory muscle training was accompanied by lower deoxygenation of the intercostal muscles and greater oxygenation of the vastus lateralis during high-intensity exercise, which the authors interpreted as an attenuated metaboreflex that could support repeated-sprint performance. This mechanism may be especially relevant to women, who typically have smaller lungs and airways than men and therefore incur a higher work and oxygen cost of breathing for a given ventilation (Dominelli & Molgat-Seon, 2022).

Although resistance training and respiratory muscle training have been widely studied as independent interventions, limited research has examined their combined effects on athletic performance. Most studies focus on a single training method, leaving uncertainty regarding whether integrating muscular and respiratory training produces additive or synergistic physiological benefits. Furthermore, collegiate women athletes remain underrepresented in experimental exercise science research. Historically, many sports performance studies have focused on male or mixed-gender samples, which may obscure potential sex-specific physiological responses to training interventions (Zouita et al., 2023). Variations in training protocols, program duration, and intensity across previous studies also contribute to inconsistent findings on anaerobic threshold and power performance.

The underrepresentation of women in this field is well documented. In an analysis of more than 5,000 publications in six leading sport and exercise science journals published between 2014 and 2020, Cowley et al. (2021) found that only 6% of studies included female participants exclusively and that women accounted for approximately one-third of all participants. Elliott-Sale et al. (2021) argue that, because of known physiological differences between the sexes, findings obtained from predominantly male samples cannot simply be assumed to apply to women, and they call for more high-quality, female-specific data. Collegiate women athletes, who must also balance training with academic demands, therefore need practical, evidence-based conditioning guidance.

Exercise science literature emphasizes integrated training approaches that target multiple physiological systems to optimize athletic performance (Subramanian & Goyal, 2025; Tosun et al., 2025; Xavier et al., 2025). Combining resistance training with respiratory muscle training may stimulate complementary adaptations in both muscular and respiratory systems, potentially enhancing high-intensity performance capacity. Such integrated approaches may be particularly beneficial for collegiate athletes who must maximize training efficiency within limited training time.

This study is grounded in Adaptation Theory (Selye, 1956) and the Specificity Principle of Exercise Physiology (Behm & Sale, 1993). Adaptation Theory explains that the human body responds to physical stress through physiological adjustments that improve functional capacity over time. Meanwhile, the Specificity Principle posits that training adaptations occur in response to the specific type, intensity, and muscles involved in the training stimulus. In this study, resistance training primarily targets neuromuscular strength and power, whereas respiratory muscle training enhances ventilatory efficiency and respiratory endurance. Integrating these

two training approaches may therefore produce complementary physiological adaptations that can influence anaerobic threshold and peak power output.

Despite growing interest in integrated training strategies, empirical research on the combined effects of resistance training and respiratory muscle training among collegiate women athletes remains limited. Most existing studies have examined these training modalities independently, focusing either on muscular strength development through resistance training or improvements in ventilatory efficiency through respiratory muscle training. Consequently, the potential contributory effects of combining these two interventions on performance-related physiological outcomes remain insufficiently explored, particularly among female collegiate athletes who are often underrepresented in exercise science research. Addressing this gap is important to identify effective, evidence-based training strategies that can enhance athletic performance in this population.

The research problem addressed by this study can therefore be stated in three parts. First, the resistance training and respiratory muscle training literatures have developed largely in parallel, so the combined contribution of the two modalities to anaerobic and power-related outcomes remains unclear. Second, the available evidence comes mainly from male or elite samples, and its transfer to collegiate women athletes cannot be assumed (Cowley et al., 2021; Elliott-Sale et al., 2021). Third, most published protocols rely on commercial threshold-loading devices and laboratory testing, whereas many university athletic programs, including those of state universities in the Philippines, operate with limited equipment, limited training time, and field-based assessment. Research was therefore needed to determine whether a practical, low-cost integrated program could produce measurable changes in anaerobic threshold and peak power output within a typical academic training block.

Thus, this study aimed to determine the contributory effects of a combined resistance training and respiratory muscle training program on anaerobic threshold and peak power output among collegiate women athletes. Specifically, the study evaluated whether participation in a structured five-week training intervention was associated with measurable improvements in anaerobic capacity and explosive power performance, thereby contributing to the development of more effective training strategies for collegiate athletic populations.

To address this problem, the study implemented a five-week, twice-weekly program that combined progressive bodyweight resistance exercises (squats, lunges, push-ups, and planks) with incentive spirometry-based inspiratory muscle training among collegiate women athletes. The researcher used a single-group quasi-experimental pretest–posttest design: we assessed anaerobic threshold with the 300-yard shuttle run and peak power output with the vertical jump test before and after the intervention, and analyzed changes with paired-sample t-tests and effect sizes. The approach was deliberately low-cost and field-based so that, if effective, university coaches with limited equipment and time could adopt it directly. The expected contribution is twofold: empirical evidence for an understudied population and a practical, transferable conditioning model for collegiate athletic programs.

Objectives of the study

General Objective

To determine the contributory effects of combined resistance training and respiratory muscle training on anaerobic threshold and peak power output among collegiate women athletes.

Specific Objectives

1. To determine the pretest anaerobic threshold and peak power output of collegiate women athletes.
2. To determine the post-test anaerobic threshold and peak power output after the five-week training intervention.
3. To determine whether there is a significant difference between the pretest and post-test anaerobic threshold.
4. To determine whether there is a significant difference between the pretest and post-test peak power output.
5. To assess the extent to which combined resistance and respiratory muscle training contributes to changes in anaerobic threshold and peak power output.

Material and methods

Research Design

This study utilized a single-group quasi-experimental longitudinal pretest-posttest design to investigate the contributory effects of a combined resistance training and respiratory muscle training (RMT) program on anaerobic threshold and peak power output. This design was selected to determine changes in performance metrics before and after the intervention among the same participants over a five-week period. The intervention was conducted twice per week, allowing repeated observation of physiological adaptations over time while maintaining consistency in training exposure.

Sampling Strategy

The study population consisted of collegiate women athletes from Bataan Peninsula State University, Orani Campus, aged 18-25 years, who actively participated in university sports and had no history of respiratory or cardiovascular conditions. Inclusion criteria required participants to be current athletes free from medical

issues that could impair exercise performance, as determined by the Physical Activity Readiness Questionnaire (PAR-Q). Exclusion criteria eliminated individuals with any interfering conditions, such as recent injuries or contraindications to high-intensity training. All participants provided written informed consent prior to involvement.

A convenience sampling approach was used, inviting women athletes from badminton, sepak takraw, taekwondo, and basketball through coordination with athletic coaches. These sports were targeted for their high-intensity intermittent demands, aligning with the study focus on anaerobic threshold and peak power output. Sixteen potential participants initially expressed interest and agreed after informational sessions, announcements, and coach referrals. Following PAR-Q screening and eligibility confirmation, only seven collegiate women athletes completed the full five-week intervention and assessments. No subgroups were formed due to group homogeneity. This approach yielded preliminary insights into an underrepresented population, typical of resource-limited university research.

Prior to the intervention, all participants were active collegiate women athletes engaged in regular university sports training. Baseline assessments were conducted to establish initial anaerobic threshold and peak power output measurements before participation in the training intervention.

Data Collection

The primary independent variable was the combined resistance and RMT program, conducted over five weeks. Resistance training incorporated exercises targeting major muscle groups, such as squats, lunges, push-ups, and planks, with progressive overload to enhance muscular strength and endurance. These exercises involved controlled 3-5 second holds, 10 repetitions per set, and one-minute rest intervals between sets. Respiratory muscle training was integrated using incentive spirometers for inspiratory muscle strengthening, where participants performed deep inhalations against resistance, holding for 3-5 seconds per repetition.

The intervention model combined progressive resistance exercises and inspiratory respiratory muscle training to simultaneously target neuromuscular adaptations and ventilatory efficiency. The integrated approach aimed to improve repeated high-intensity performance through combined muscular and respiratory conditioning.

Anaerobic threshold was assessed using a 300-yard shuttle run test, which measures repeated sprint endurance and lactate tolerance under high-intensity conditions. Peak power output was evaluated using a vertical jump test, which quantifies explosive lower-body power through jump height. These assessments followed standardized protocols to maintain reliability and validity. Participants underwent pretest evaluations to establish baselines, followed by the intervention at the university athletic facilities with flexible scheduling to accommodate academic and team commitments. Sessions lasted about 45 minutes each and included warm-up, integrated resistance and RMT circuits, and cool-down activities. Post-test assessments were performed under identical conditions within 48 hours of the final session to capture immediate intervention-related changes, and trained team members conducted all measurements to reduce variability. All participants complied with the prescribed training sessions and successfully completed both the pretest and post-test assessments.

Data Analysis

Data analysis began with descriptive statistics to summarize participant characteristics, including means and standard deviations for age, experience, and performance metrics. Inferential statistics employed paired-sample t-tests to compare pretest and post-test scores for anaerobic threshold and peak power output, assessing the significance of changes associated with the intervention. Effect sizes were calculated as Cohen's d_z (the mean of the pretest–post-test differences divided by the standard deviation of those differences) and interpreted as small (0.2), medium (0.5), or large (0.8). Statistical significance was set at $p < 0.05$. No subgroup analyses were conducted due to the limited sample size, but individual response variability was noted to inform future research directions.

Ethical Considerations

This study adhered to established ethical standards in conducting research involving human participants. Participants were informed about the purpose, procedures, potential risks, and benefits of the study before their participation. Written informed consent was obtained from all participants to ensure voluntary participation. Participants were assured that their personal information and responses would remain confidential and would be used solely for research purposes. Data collected during the study were anonymized to protect the identity of the participants. In addition, participants were informed that they had the right to withdraw from the study at any time without penalty or negative consequences. To ensure participant safety, only individuals who met the inclusion criteria and passed the Physical Activity Readiness Questionnaire screening were allowed to participate. All training sessions were supervised, and appropriate precautions were implemented to minimize the risk of injury during the intervention.

Results

This study employed a single-group quasi-experimental pretest-posttest design to examine the contributory effects of a five-week combined resistance training and respiratory muscle training program among collegiate women athletes. Initially, sixteen athletes expressed interest in participating in the study. However, after eligibility screening using the Physical Activity Readiness Questionnaire and confirmation of the inclusion

criteria, only seven participants were able to complete both the pretest and post-test assessments and the full training protocol.

All seven participants successfully completed the training program and both assessment sessions. No injuries, adverse events, or withdrawals occurred during the intervention period. The participants were collegiate women athletes aged 18-25 years ($M = 21.3 \pm 2.1$ years) with an average collegiate competitive experience of 4.2 ± 1.8 years. The training sessions were conducted at the university athletic facilities and included warm-up activities, integrated resistance and respiratory muscle training circuits, and cool-down exercises.

Anaerobic Threshold

Table 1 presents the individual pretest and post-test results of the participants in the 300-yard shuttle run test, which was used to measure anaerobic threshold.

Table 1. Individual Pre-test and Post-test Results for the 300-Yard Shuttle Run

Participant	Pretest (seconds)	Post-test (seconds)	Difference (seconds)
P1	92.43	80.15	-12.28
P2	89.87	67.43	-22.44
P3	95.56	83.69	-11.87
P4	98.74	83.77	-14.97
P5	139.40	84.80	-54.60
P6	127.63	76.85	-50.78
P7	59.32	66.93	+7.61

Note. Negative values indicate improved performance (shorter completion time), while positive values indicate longer completion time in the post-test compared to the pre-test.

As shown in Table 1, the majority of participants demonstrated improved shuttle run performance during the post-test. Six out of the seven participants recorded shorter completion times compared with their pretest results. The improvements ranged from 11.87 seconds to 54.60 seconds, indicating notable reductions in the time required to complete the shuttle run. However, Participant 7 recorded a longer completion time during the post-test. Despite this individual variation, the descriptive results show that most participants completed the shuttle run in a shorter time during the post-test assessment.

Table 2. Paired t-test Results for the 300-Yard Shuttle Run (Anaerobic Threshold)

Test	Mean (seconds)	Standard Deviation	t-value	p-value	Interpretation
Pre-test Shuttle Run	96.14	26.17			
Post-test Shuttle Run	73.37	5.12	2.688	0.036	Significant

Note. Significance level set at $\alpha = 0.05$.

As presented in Table 2, the mean shuttle run time decreased from 96.14 seconds in the pretest to 73.37 seconds in the post-test, indicating a reduction in the average completion time following the training intervention. The paired t-test yielded a t-value of 2.688 with a p-value of 0.036. Since the computed p-value is less than the significance level of 0.05, the null hypothesis stating that there is no significant difference between pretest and post-test shuttle run performance was rejected. This result indicates that there is a statistically significant difference between the pretest and post-test shuttle run completion times among the participants who completed the training program. The magnitude of this change was large (Cohen's $d_z = 1.02$), calculated from the individual difference scores in Table 1.

Peak Power Output

Table 3 presents the individual pretest and post-test results of the participants in the vertical jump test, which was used to measure peak power output.

Table 3. Individual Pretest and Post-test Results for the Vertical Jump Test

Participant	Pretest (cm)	Post-test (cm)	Difference (cm)
P1	38	38	0
P2	41	38	-3
P3	39	37	-2
P4	35	37	+2
P5	35	40	+5
P6	39	40	+1
P7	40	41	+1

Note. Positive values indicate improvement in jump height.

As shown in Table 3, the individual results of the vertical jump test demonstrate slight variations between the pretest and post-test performances. Four participants (P4-P7) showed small improvements in jump height, one participant maintained the same jump height, and two participants recorded slight decreases. Overall, the individual results indicate that changes in vertical jump performance were relatively small and inconsistent across participants.

Table 4. Paired t-test Results for Peak Power Output (Vertical Jump Test)

Test		Mean (cm)	Standard Deviation	t-value	p-value	Interpretation
Pretest	Vertical Jump	38.14	3.18			
Post-test	Vertical Jump	38.71	2.50	0.573	0.587	Not Significant

Note. Significance level set at $\alpha = 0.05$.

As presented in Table 4, the mean vertical jump height increased slightly from 38.14 cm in the pretest to 38.71 cm in the post-test. The paired t-test analysis yielded a t-value of 0.573 with a p-value of 0.587. Since the computed p-value is greater than the significance level of 0.05, the null hypothesis stating that there is no significant difference between pretest and post-test vertical jump performance was not rejected. These results indicate that there was no statistically significant difference in peak power output between the pretest and post-test measurements among the participants who completed the training program. The corresponding effect size was small (Cohen's $d_z = 0.22$).

These findings suggest that the five-week combined resistance training and respiratory muscle training program may not have been sufficient to produce significant improvements in peak power output among the participants. While slight increases in jump height were observed, the changes were minimal and may require a longer intervention period or more power-specific training protocols to achieve statistically significant improvements.

Discussion

This study addressed the problem of limited empirical evidence on the combined effects of resistance training and respiratory muscle training on anaerobic threshold and peak power output, particularly in an underrepresented group: collegiate women athletes in the Philippines. The findings revealed a significant improvement in anaerobic performance, as indicated by the reduction in 300-yard shuttle run time from 96.14 seconds in the pretest to 73.37 seconds in the post-test, representing an average improvement of approximately 22.77 seconds. The paired t-test analysis showed that this difference was statistically significant ($t = 2.688$, $p = 0.036$), indicating that the training intervention contributed to enhanced anaerobic performance among the participants. In contrast, peak power output measured through the vertical jump test showed only a minimal increase from a pretest mean of 38.14 cm to a post-test mean of 38.71 cm, and the change was not statistically significant ($t = 0.573$, $p = 0.587$). These findings suggest that the integrated training intervention was associated with improved anaerobic endurance but did not produce measurable improvements in explosive power within the five-week training period.

The significant improvement in the 300-yard shuttle run performance supports existing literature demonstrating the ergogenic effects of respiratory muscle training on high-intensity exercise capacity. By strengthening the muscles involved in breathing, RMT can improve ventilatory efficiency, delay respiratory muscle fatigue, and increase tolerance for repeated bursts of high effort. Previous studies have reported that strengthening the respiratory muscles can improve ventilatory efficiency, reduce respiratory muscle fatigue, and enhance tolerance to repeated high-intensity efforts (HajGhanbari et al., 2013; Illi et al., 2012; León-Morillas et al., 2021). These findings support the present results, indicating that improved respiratory muscle function may enhance athletes ability to sustain high-intensity activities.

Systematic reviews and meta-analyses also provide evidence supporting the role of respiratory muscle training in improving exercise performance. Shei (2018) reported that respiratory muscle training produces ergogenic effects across multiple sports by improving ventilatory efficiency and reducing respiratory muscle fatigue during intense exercise. Likewise, Fernandez-Lazaro et al. (2022) found that inspiratory muscle training significantly improves respiratory parameters and athletic performance. More recently, Xavier et al. (2025) concluded that respiratory muscle training effectively enhances respiratory muscle strength and exercise capacity in athletes. The improvement observed in shuttle run performance in the present study may therefore be associated with enhanced respiratory efficiency and improved tolerance to repeated high-intensity efforts.

In addition to respiratory adaptations, resistance training may also contribute to improved anaerobic performance. Resistance training has been shown to improve muscular endurance, sprint ability, and repeated sprint performance in athletes. Rath et al. (2023) reported that resistance training significantly improved sprint performance and agility among female team sport athletes. Similarly, Hughes et al. (2023) found that strength training interventions produced improvements in sprint performance among female athletes participating in team sports. These findings support the results of the present study, suggesting that the combined effects of resistance training and respiratory muscle training may contribute to improved anaerobic endurance during repeated sprint activities.

The findings of the present study also align with Adaptation Theory proposed by Selye (1956). According to this theory, the body responds to repeated exposure to physiological stress through adaptive processes that enhance functional capacity. In this study, the repeated exposure to resistance exercises and respiratory muscle training likely acted as training stimuli that triggered physiological adaptations in both the

muscular and respiratory systems. These adaptations may have improved the athletes ability to tolerate high-intensity exercise and sustain repeated sprint efforts, resulting in improved shuttle run performance.

Furthermore, the results of this study are consistent with the Specificity Principle of Exercise Physiology proposed by Behm and Sale (1993), which states that training adaptations occur in response to the specific demands imposed by the training stimulus. The training intervention implemented in this study primarily emphasized sustained muscular effort and respiratory conditioning rather than explosive power development. Consequently, the adaptations observed were more closely associated with improvements in anaerobic endurance rather than maximal power output. The significant improvement in shuttle run performance but the absence of significant change in vertical jump height supports the concept that training outcomes are specific to the type of exercise stimulus applied.

The absence of significant improvement in peak power output may therefore be attributed to the nature and duration of the training intervention. Previous studies that reported improvements in vertical jump performance typically involved longer training durations or training programs that specifically targeted explosive power development. For example, Koç and Sarıtaş (2019) reported improved vertical jump performance only after eight weeks of respiratory muscle training performed three times per week, and studies targeting jump height directly have relied on plyometric or combined resistance–plyometric stimuli (Budhathoki et al., 2025), with meta-analytic evidence showing a meaningful effect of plyometric jump training on vertical jump height (Ramirez-Campillo et al., 2020). Resistance training effects on jump performance also follow a dose–response pattern in which longer programs produce larger gains (Lesinski et al., 2016). These findings suggest that the five-week intervention implemented in the present study may not have provided sufficient stimulus for neuromuscular adaptations associated with explosive power development. A noteworthy interpretation of these findings relates to the potential improvement in respiratory-metabolic efficiency during repeated high-intensity efforts resulting from the combined resistance and respiratory muscle training program. The substantial reduction in shuttle run time within a relatively short five-week intervention suggests that the training may have reduced the physiological cost of breathing during high-intensity exercise. Strengthening the inspiratory muscles can delay respiratory muscle fatigue and attenuate the respiratory muscle metaboreflex, a physiological response that restricts blood flow to the working limb muscles when the respiratory muscles become fatigued (Subramanian & Goyal, 2025). By reducing activation of this reflex, a greater proportion of oxygenated blood can be directed to the active leg muscles, improving endurance during repeated sprint activities. This interpretation is consistent with Archiza et al. (2018), who observed improved locomotor muscle oxygenation after inspiratory muscle training in professional women football players.

The individual data also deserve attention. The two largest improvements in shuttle run time were recorded by the participants with the slowest pretest times (P5 and P6), whereas the participant with by far the fastest pretest time (P7) did not improve. This pattern is consistent with the observation that less-fit individuals tend to benefit most from respiratory muscle training (Illi et al., 2012), but it may also partly reflect regression toward the mean and day-to-day variability in field testing, which cannot be separated from a true training effect in a single-group design. In addition, the respiratory stimulus in the present program (incentive spirometry twice per week) was modest compared with the threshold-loading protocols of six to eight weeks at high weekly frequency that have typically improved intermittent performance in team sports (Kowalski et al., 2025). That a measurable change in anaerobic performance was nonetheless observed suggests that even a low-dose, low-cost respiratory stimulus, combined with resistance training, may be worthwhile for collegiate women athletes, for whom the relatively higher cost of breathing may make respiratory conditioning particularly relevant (Dominelli & Molgat-Seon, 2022).

Although the sample size was limited to seven participants, the study provides preliminary evidence regarding integrated resistance training and respiratory muscle training among collegiate women athletes, an underrepresented population in exercise science research. However, since participants continued their regular university sports practices throughout the intervention period, some performance improvements may also have been influenced by ongoing athletic training outside the experimental sessions. This limitation should be considered in interpreting the extent to which the observed changes may be attributed to the intervention.

Overall, the results of this study contribute to the growing body of literature examining integrated training approaches for athletic performance. While the benefits of resistance training and respiratory muscle training have been widely studied individually, fewer studies have explored their combined effects, particularly among female collegiate athletes. By examining the contributory effects of a combined training program within a university athletic context, the present study provides additional evidence regarding the potential role of respiratory muscle training as a complementary component of athletic conditioning programs.

Recommendations

Based on the findings of the study, the following recommendations are proposed:

1. For coaches and strength and conditioning specialists, respiratory muscle training (RMT) may be incorporated as a complementary component of athletic conditioning programs to improve anaerobic endurance and tolerance to repeated high-intensity efforts. Integrating RMT into regular training sessions may help athletes enhance breathing efficiency, delay respiratory muscle fatigue, and sustain performance during intermittent high-

intensity activities commonly observed in competitive sports such as basketball, volleyball, and soccer. The use of RMT devices or structured breathing exercises may therefore serve as a practical and low-cost strategy to enhance overall conditioning in collegiate athletic programs.

2. Athletic training programs aimed at improving peak power output should consider incorporating more explosive training modalities such as plyometric exercises, power-based resistance training, or velocity-based training protocols. These types of training emphasize rapid force production and neuromuscular activation, which are essential for improving explosive performance indicators such as vertical jump height and sprint acceleration. Strength and conditioning practitioners may therefore design training programs that combine traditional resistance exercises with explosive movements to maximize improvements in muscular power.

3. Longer training interventions, such as programs lasting eight to twelve weeks, may be implemented in future conditioning programs to allow sufficient time for neuromuscular adaptations associated with explosive power development. While the present study demonstrated improvements in anaerobic endurance within a five-week period, adaptations related to muscular power and explosive strength typically require longer periods of consistent training. Extending the duration of the training program may therefore produce more substantial improvements in peak power output among athletes.

4. Future researchers are encouraged to replicate this study with a larger sample size and include a control group in order to strengthen the validity and generalizability of the findings. A larger and more diverse sample may provide a clearer understanding of how combined resistance training and respiratory muscle training influence performance outcomes across different athletic populations. Including a control group would also allow researchers to more clearly isolate the effects of the training intervention and reduce potential confounding factors.

5. Further studies may also incorporate physiological measurements, such as blood lactate concentration, respiratory muscle strength, pulmonary function, or maximal oxygen uptake ($\text{VO}_{2\text{max}}$), to provide deeper insight into the mechanisms underlying performance improvements. These physiological indicators may help researchers better understand how respiratory muscle training and resistance training influence metabolic efficiency, oxygen utilization, and fatigue resistance during high-intensity exercise.

6. Future investigations may explore sport-specific adaptations by examining the effects of combined resistance and respiratory muscle training across different sports or competitive levels. Because physical and physiological demands vary across sports, examining athletes from different disciplines may help determine how integrated training programs can be tailored to specific performance requirements. Additionally, studies may compare responses among male and female athletes or across varying levels of competition to better understand the broader applicability of this training approach.

Conclusion

This study demonstrates that a five-week integrated resistance training and respiratory muscle training (RMT) program significantly enhances anaerobic capacity among collegiate women athletes. The notable reduction in 300-yard shuttle run completion times suggests that combining muscular conditioning with inspiratory muscle exercise improves ventilatory efficiency, delays respiratory muscle fatigue, and enhances high-intensity effort tolerance. These findings support both Selye's Adaptation Theory and the Specificity Principle by showing that targeted metabolic and respiratory stress leads to clear functional endurance adaptations. In contrast, the intervention did not produce a statistically significant improvement in peak power output, as measured by vertical jump height. This outcome highlights the limitations of a short five-week program and indicates that explosive power development requires specific high-velocity, neuromuscular stimuli (e.g., plyometrics or power-based lifts) maintained over a longer training duration.

Overall, integrated resistance and respiratory muscle training serves as an effective, practical strategy for improving anaerobic performance in female collegiate athletes. While RMT is valuable for building anaerobic endurance and metabolic efficiency, strength and conditioning practitioners should pair it with dedicated, power-focused training protocols and extended intervention periods to achieve meaningful gains in explosive mechanical power.

Taken together, the findings answer the study objectives in a differentiated way. Mean 300-yard shuttle run time decreased by 22.77 seconds ($t = 2.688$, $p = 0.036$), a large effect ($d_z = 1.02$), with six of the seven athletes improving, whereas vertical jump height changed by only 0.57 cm ($t = 0.573$, $p = 0.587$; $d_z = 0.22$), with individual changes ranging from -3 cm to $+5$ cm. The combined program therefore contributed to anaerobic, fatigue-resistant performance but not to maximal explosive output within five weeks.

The theoretical contribution of the study lies in showing that Adaptation Theory and the Specificity Principle operate together within an integrated program; the athletes adapted to the stresses the program actually imposed, namely sustained muscular effort and inspiratory loading, and not to a stress it did not impose, namely high-velocity, maximal-intent contractions. The results also add a female-only sample from a Southeast Asian university to a literature that remains dominated by male participants (Cowley et al., 2021), and they are consistent with the proposition that attenuation of the respiratory muscle metaboreflex is a plausible pathway through which inspiratory training transfers to repeated high-intensity running (Archiza et al., 2018; Dempsey et al., 2006).

The practical contribution is a low-cost, low-equipment conditioning model. Incentive spirometers and bodyweight exercises require minimal space and budget, fit into two 45-minute sessions per week, and can be delivered alongside regular team practice, which makes the approach feasible for university athletic programs with limited resources. For coaches and strength and conditioning practitioners, the key message is that inspiratory muscle training is a useful addition when the goal is repeated-sprint endurance and fatigue tolerance, qualities central to badminton, basketball, sepak takraw, and taekwondo, but it should not be expected to increase jump height or peak power on its own. Where explosive performance is the priority, the program should be extended to at least eight weeks and paired with plyometric, power-oriented, or velocity-based resistance training (Ramirez-Campillo et al., 2020; Weakley et al., 2021).

Because the study used a single group, a small sample, and participants who continued their regular sports training, the findings should be regarded as preliminary evidence of a contributory rather than a causal effect. Controlled trials with larger female samples, direct physiological measures such as blood lactate concentration and maximal inspiratory pressure, and longer intervention periods are needed to confirm the size of the effect and to establish the optimal dose of combined resistance and respiratory muscle training for collegiate women athletes.

Limitations

This study has several limitations. First, the single-group pretest–posttest design without a control group does not allow the observed changes to be attributed solely to the intervention; learning effects, regression toward the mean, and the participants' ongoing university sports training may have contributed. Second, only seven athletes took part in the study, and they came from four different sports. With so few participants, it is harder to be sure the results are reliable or that they apply to other athletes. Third, the 300-yard shuttle run and the vertical jump are field tests that provide indirect estimates of anaerobic threshold and peak power output; direct measures such as blood lactate, ventilatory thresholds, force-plate power, or maximal inspiratory pressure were not collected, so the proposed physiological mechanisms could not be verified. Fourth, the inspiratory load provided by incentive spirometry was not individually prescribed or progressed relative to maximal inspiratory pressure. Finally, menstrual cycle phase and hormonal contraceptive use were not recorded, although current methodological guidance recommends documenting them when women are research participants (Elliott-Sale et al., 2021).

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