

An Analysis of Respiratory Function Recovery Dynamics in Vietnamese Athletes from Selected Key Sports Following Submaximal Capacity Exertion

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Cite this paper as: Nguyen Van Hoa, Le Thi My Hanh, Nguyen Huu Hung, Dao Tien Dan, Tran Tuan Hieu, Lim Boon Hooi, (2025) An Analysis of Respiratory Function Recovery Dynamics in Vietnamese Athletes from Selected Key Sports Following Submaximal Capacity Exertion. *Journal of Neonatal Surgery*, 14 (31s), 45-50.

ABSTRACT

In sports, monitoring respiratory function indicators across different exercise intensity zones and at various time intervals is crucial for accurately evaluating the physiological impact of exercise on an athlete's body and informing effective training and recovery strategies. This information is essential for tailoring individualized training programs, optimizing athletic performance, and reducing the risk of overtraining. Additionally, monitoring recovery dynamics enables precise assessment of an athlete's recovery status, supporting informed decisions on training load adjustments and readiness for subsequent exercise sessions. The primary objective of this study is to examine the respiratory function recovery dynamics in Vietnamese athletes from four key sports, athletics, table tennis, shooting, and Pencak Silat following submaximal capacity exertion. By analysing sport-specific physiological responses and recovery patterns, the study aims to contribute valuable insights that can enhance training monitoring and optimize recovery strategies for high-performance athletes in Vietnam. This study recruited a total of 76 athletes, including 49 males and 27 females. All participants were in the professional training phase, classified at Level I or higher, and were actively training at the Sports Training and Competition Centre in Bac Ninh Province, Vietnam. Results revealed that athletes generally demonstrate superior respiratory function compared to non-athletes, primarily due to physiological adaptations resulting from consistent, structured training regimens. A comparison of the four sports examined in this study, athletics, table tennis, shooting, and Pencak Silat revealed distinct differences in respiratory function recovery dynamics before, during, and after submaximal exercise. Athletes from athletics and Pencak Silat exhibited more favourable recovery patterns compared to their counterparts in table tennis and shooting. The current findings align with previous research on respiratory recovery patterns surrounding submaximal exercise. Consistent with earlier studies, this investigation observed an initial stabilization or slight decline in respiratory rate during exercise, followed by a sharp increase immediately post-exertion, and a gradual return to baseline values during the recovery period.

Keywords: Recovery, respiratory function, key sports, submaximal capacity

1. INTRODUCTION

Respiratory function recovery dynamics encompass the physiological processes and time course by which pulmonary function is restored following acute or chronic impairment. This recovery can result from various conditions, including respiratory infections, surgical procedures, chronic obstructive pulmonary disease (COPD) exacerbations, and ventilator weaning. Understanding the mechanisms and timelines of respiratory function recovery is critical for optimizing treatment protocols, minimizing complications, and enhancing patient outcomes. The recovery process involves complex interactions among respiratory muscles, lung parenchyma, and neural control systems, influenced by factors such as age, comorbidities,

and the severity of the underlying condition (Gattinoni et al., 2020). A comprehensive understanding of these dynamics is essential for clinicians to guide rehabilitation strategies and improve functional respiratory outcomes.

Monitoring the recovery of respiratory function indicators across various exercise capacity zones and at different time intervals is essential for accurately assessing the physiological impact of exercise on an athlete's body. By evaluating how respiratory parameters such as tidal volume, respiratory rate, and oxygen uptake recover after training sessions of differing intensities, practitioners can determine not only the immediate stress placed on the respiratory system but also the athlete's current level of conditioning and adaptability. This information is vital for individualizing training programs, optimizing performance, and preventing overtraining. Furthermore, tracking these recovery dynamics allows for precise identification of an athlete's recovery status, which can inform decisions regarding training load adjustments and readiness for subsequent exercise bouts (Borresen & Lambert, 2009). Ultimately, such assessments contribute to a more evidence-based and athlete-specific approach to sports training and rehabilitation.

Respiratory function recovery dynamics refer to the process by which the respiratory system returns to baseline function following physical exertion. Key indicators of this recovery include vital capacity (VC), relative oxygen uptake (VO_2/kg), and relative carbon dioxide output (VCO_2/kg). Vital capacity represents the maximum amount of air an individual can exhale after a maximal inhalation, serving as a fundamental measure of pulmonary performance and lung elasticity. Relative VO_2 and VCO_2 , expressed per kilogram of body weight, provide insights into the metabolic efficiency and respiratory exchange during and after exercise. Monitoring these parameters during recovery allows researchers and practitioners to assess how efficiently the body restores homeostasis after submaximal or maximal exertion. Rapid normalization of these indices is generally associated with higher cardiorespiratory fitness and training adaptation, whereas delayed recovery may indicate fatigue, overtraining, or reduced aerobic conditioning (Wilmore, Costill, & Kenney, 2008). Understanding the dynamics of these variables is critical in optimizing training load, guiding recovery strategies, and enhancing overall athletic performance.

Submaximal capacity exertion refers to physical activity performed below an individual's maximal effort or oxygen uptake ($\text{VO}_{2\text{max}}$) and plays a crucial role in both athletic training and performance assessment. Unlike maximal exertion, which tests the upper limits of an athlete's physiological capacity, submaximal effort reflects more realistic and sustainable intensities encountered during competition and regular training sessions. Assessing physiological responses to submaximal exercise such as heart rate, respiratory function, and lactate levels offers valuable insights into an athlete's aerobic efficiency, endurance capacity, and recovery dynamics without inducing extreme fatigue or risk of injury (Bentley et al., 2007). In high-performance sports, understanding submaximal performance markers is essential for monitoring training adaptations, optimizing load, and preventing overtraining. Moreover, submaximal testing is particularly useful in longitudinal athlete monitoring due to its repeatability and safety across various training phases.

A strong scientific basis for evaluating the effectiveness of training is critical to the development of high-level athletes, particularly in countries like Vietnam, where targeted investment in key sports such as athletics, swimming, and martial arts has become a national priority. Objective evaluation using physiological, biomechanical, and performance-based indicators enables coaches and sports scientists to accurately assess the training outcomes, identify individual response patterns, and optimize load management strategies. In elite training environments, relying on empirical observation alone is insufficient; instead, evidence-based practices such as monitoring VO_2 max, lactate thresholds, heart rate variability, and neuromuscular fatigue offer deeper insights into athletes' adaptation and performance potential (Issurin, 2010). Applying these principles helps not only to enhance athletic performance but also to minimize injury risks and overtraining, which are critical factors in maintaining long-term competitive success in international arenas. For Vietnam, integrating such scientific methodologies into national training programs represents a pivotal step toward achieving higher performance standards in global competitions.

The primary objective of the current study is to investigate the respiratory function recovery dynamics in Vietnamese athletes from selected key sports, namely athletics, table tennis, shooting, and Pencak Silat, following submaximal capacity exertion. This research aims to provide insight into the physiological responses and recovery patterns specific to each sport, thereby contributing to more effective training monitoring and recovery strategies for high-performance athletes in Vietnam.

2. METHODS

Participants

The study involved 76 athletes, comprising 49 males and 27 females, representing four sports disciplines: athletics, table tennis, shooting, and Pencak Silat. All participants were in the professional training phase, classified at level I or higher, and were undergoing training at the Sports Training and Competition Centre in Bac Ninh Province, Vietnam.

Instrumental

The research team employed the Kostex Metamax 3B system to analyse respiratory function indices of athletes at multiple time points to capture dynamic physiological changes. Measurements were taken at three key stages: prior to exercise (before

the athletes engaged in any training activity), during exercise (specifically 10 seconds following the completion of the main training activity), and at 10 minutes post-exercise. To represent submaximal exercise capacity, the 400-meter run was selected as the standardized performance test. This methodological approach enables precise monitoring of respiratory responses to varying exercise intensities and recovery phases, providing valuable insights into training adaptations (Binder et al., 2008).

Procedures

This study received ethical approval from the Ethics Committee of Bac Ninh University of Physical Education and Sports, Vietnam. In addition, official approval was obtained from the respective sports associations overseeing the participating athletes. Written informed consent was secured from all recruited athletes prior to their involvement in the study. An initial meeting was conducted with all relevant stakeholders, during which the research objectives, procedures, and ethical considerations were thoroughly explained. Full agreement to proceed with the study was obtained from all parties involved.

3. RESULTS

Table 1. Respiratory Function Recovery Dynamics in Vietnamese Athletes from Selected Key Sports Following Submaximal Capacity Exertion Before Exercise

Athletes	Gender	Vital	Capacity	Relative VO ₂		Relative VCO ₂	
		$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ
Athletics	Males	3.25	0.34	5.71	0.53	4.85	0.47
	Females	3.16	0.33	5.68	0.51	4.71	0.48
Table Tennis	Males	3.18	0.24	5.53	0.54	4.53	0.44
	Females	3.11	0.21	5.27	0.46	4.37	0.42
Shooting	Males	3.04	0.12	5.61	0.57	4.71	0.48
	Females	2.77	0.15	5.49	0.53	4.67	0.47
Pencak Silat	Males	3.23	0.21	5.49	0.55	4.67	0.48
	Females	3.22	0.23	5.52	0.56	4.75	0.48

As shown in Table 1, prior to exercise, the respiratory function indicators of athletes across all four sports: athletics, table tennis, Pencak Silat, and shooting, all fall within the normal range for the general population. However, when compared to normative values for individuals of the same age and gender, these athletes demonstrate respiratory function that is categorized as average to good according to the performance standards established for Vietnamese athletes (Nguyen et al., 2016). This suggests a baseline level of cardiorespiratory fitness appropriate for athletes undergoing professional training, though with potential room for improvement depending on the sport-specific demands.

Athletes typically exhibit superior respiratory function compared to non-athletes due to the physiological adaptations that occur in response to consistent and structured training. Regular physical training especially aerobic and high-intensity interval training which enhances lung ventilation, increases tidal volume, and improves the efficiency of gas exchange in the alveoli. These adaptations result in improved indicators such as vital capacity, oxygen uptake (VO₂), and respiratory muscle strength. Furthermore, elite athletes often develop more efficient breathing patterns and greater respiratory endurance, which collectively contribute to higher overall respiratory performance (Wilmore, Costill, & Kenney, 2008). In contrast, sedentary individuals generally have less developed respiratory systems due to the absence of sustained physical stimuli, leading to lower lung volumes and reduced cardiorespiratory efficiency. These differences underscore the significant role of long-term physical conditioning in enhancing pulmonary function.

When comparing the respiratory function across the four studied sports, athletes in athletics and Pencak Silat exhibited the most favourable respiratory function indicators. These were followed by athletes in shooting and table tennis, who showed comparatively lower values. This variation may be attributed to the differing physiological demands and training intensities characteristic of each sport, with endurance-based and high-intensity disciplines such as athletics and Pencak Silat placing greater demands on the respiratory system and thereby promoting more advanced respiratory adaptations (McArdle, Katch, & Katch, 2015).

To assess respiratory parameters during exercise period, gathered data on respiratory parameters and analysed the athletes' gas exchange 10 seconds after they completed the test using the Kostex Metamax 3B system. The Kostex Metamax 3B is a portable cardiopulmonary exercise testing (CPET) system developed by CORTEX Biophysik GmbH. It is designed for both laboratory and field assessments, enabling real-time analysis of respiratory gas exchange during various physical activities. Research has demonstrated the Metamax 3B's validity and reliability in measuring respiratory gas exchange. For instance, a study by Macfarlane and Wong (2012) confirmed its accuracy in assessing oxygen uptake (VO₂) and carbon dioxide

production (VCO₂) during exercise.

Table 2. Respiratory Function Recovery Dynamics in Vietnamese Athletes from Selected Key Sports Following Submaximal Capacity Exertion During Exercise

Athletes		Vital capacity (litres)			Relative VO ₂ (ml/min/kg)			Relative VCO ₂ (ml/min/kg)		
		$\bar{x}$	σ	%	$\bar{x}$	σ	%	$\bar{x}$	σ	% change
Athletics	Males	3.40	0.34	-4.76	48.12	4.65	486.11	53.41	5.31	665.23
	Females	3.25	0.32	-6.34	48.12	4.78	484.69	53.89	5.33	661.22
Table tennis	Males	3.43	0.31	-3.38	47.23	4.61	464.95	51.95	5.03	614.62
	Females	3.37	0.32	-3.16	46.13	4.56	440.80	51.20	5.03	581.81
Shooting	Males	3.41	0.34	-2.85	48.27	4.75	454.19	53.58	5.21	599.47
	Females	3.26	0.31	-6.59	47.12	4.62	444.74	52.77	5.19	600.86
Pencak Silat	Males	3.39	0.33	-5.31	46.23	4.52	430.77	51.78	5.11	583.08
	Females	3.33	0.32	-4.86	45.21	4.09	422.66	50.18	5.12	559.44

Table 2 indicates that during submaximal exercise, the athletes exhibited significant changes in respiratory function parameters, with these changes being more pronounced than those observed during lower-intensity exercise. The respiratory rate showed a slight decrease during exercise, followed by a sharp increase compared to pre-exercise levels, rising by approximately 120 to 130%. This pattern reflects the body's compensatory response to the oxygen and nutrient deficit incurred during submaximal exercise. Notably, the most significant rise in respiratory parameters occurred within the first 10 seconds after exercise completion. Also, during submaximal exercise, both relative VO₂ (ml/min/kg) and relative VCO₂ (ml/min/kg) increase rapidly; however, the rise in relative VCO₂ occurs at a faster rate. This disproportionate increase in carbon dioxide output contributes to a slight elevation in the respiratory exchange ratio, reflecting a shift in substrate utilization and increased metabolic activity (Powers & Howley, 2018).

During exercise at submaximal capacity, athletes exhibit significant changes in respiratory function characteristics, with notable alterations in parameters such as Vital capacity (litres), Relative VO₂ (ml/min/kg) and Relative VCO₂ (ml/min/kg). These changes tend to be more pronounced when compared to exercise performed under similar submaximal conditions but with additional performance aids or interventions. For example, studies have shown that submaximal exercise leads to a marked increase in ventilatory response to accommodate metabolic demands, and this response is amplified by factors such as training status, environmental conditions, or supplementation (Amann et al., 2007; Powers & Howley, 2018).

Respiratory function data were collected from high-level athletes 10 minutes after performing exercise at submaximal capacity. These post-exercise measurements were then compared to baseline values obtained prior to the exercise session to evaluate changes in respiratory parameters and assess recovery dynamics (Powers & Howley, 2018).

Table 3. Respiratory Function Recovery Dynamics in Vietnamese Athletes from Selected Key Sports Following Submaximal Capacity Exertion After Exercise

		Vital Capacity			Relative VO ₂			Relative VCO ₂ (ml/min/kg)		
		$\bar{x}$	σ	%	$\bar{x}$	σ	%	$\bar{x}$	σ	% recovery
Athletics	Males	3.50	0.34	58.82	7.94	0.80	100.68	6.67	0.67	100.67
	Females	3.39	0.32	63.64	8.01	0.82	100.55	6.81	0.67	100.58
Table Tennis	Males	3.51	0.34	66.67	8.12	0.80	100.62	6.98	0.64	100.64
	Females	3.42	0.34	45.45	8.35	0.81	100.48	7.18	0.70	100.75
Shooting	Males	3.47	0.34	60.00	8.41	0.79	100.76	7.23	0.73	100.93
	Females	3.41	0.32	65.22	8.40	0.81	100.65	7.39	0.74	100.31
Pencak Silat	Males	3.50	0.34	57.89	8.66	8.54	100.13	7.36	0.73	100.50
	Females	3.42	0.33	52.94	8.51	0.84	100.38	7.57	7.53	100.08

As shown in Table 3, respiratory function in athletes had returned to pre-exercise levels by 10 minutes after completing submaximal exercise. Notably, some indicators demonstrated improved values compared to baseline, potentially reflecting the positive effects of the warm-up on post-exercise recovery (Powers & Howley, 2018).

Elite athletes demonstrate a significantly faster return of respiratory function to pre-exercise levels compared to untrained individuals. This rapid recovery offers several physiological advantages, including more efficient removal of metabolic by

products such as carbon dioxide, quicker restoration of acid-base balance, and improved readiness for subsequent physical activity. These adaptations are largely attributed to enhanced pulmonary ventilation efficiency, greater cardiorespiratory fitness, and superior autonomic regulation developed through rigorous training (Powers & Howley, 2018). In contrast, untrained individuals often experience prolonged respiratory recovery, reflecting lower aerobic capacity and less efficient metabolic control.

4. DISCUSSION AND CONCLUSION

This study represents the initial data collection for four distinct groups of elite athletes in Vietnam, specifically from Athletics, Table Tennis, Shooting, and Pencak Silat. These athletes are considered strong medal contenders for the Vietnamese national team in upcoming international competitions.

The findings of the current study may serve as an initial reference for understanding the dynamics of respiratory function recovery in Vietnamese athletes from selected key sports specifically before, during, and after submaximal exercise. These insights contribute to the development of sport-specific training and recovery strategies aimed at optimizing performance (Powers & Howley, 2018).

This study successfully achieved its primary objective of investigating the respiratory function recovery dynamics in Vietnamese athletes from selected key sports, namely athletics, table tennis, shooting, and Pencak Silat following submaximal capacity exertion. Comprehensive data were collected at three critical time points: before, during, and after submaximal exercise, providing valuable insights into the physiological responses and recovery patterns of these elite athletes (Powers & Howley, 2018).

When compared to normative values for individuals of the same age and gender, the results of the current study indicate that these athletes exhibit respiratory function classified as average to good based on the performance standards established for Vietnamese athletes (Nguyen et al., 2016). This reflects an adequate baseline level of cardiorespiratory fitness consistent with professional training demands, while also suggesting potential for further enhancement depending on the specific physiological requirements of each sport.

During submaximal exercise, athletes exhibited significant changes in respiratory function parameters, with greater variability observed compared to the period spent within the submaximal capacity zone. Respiratory frequency decreased slightly during exercise but rose sharply immediately after, reaching 120–130% of pre-exercise levels. This post-exercise increase is likely a compensatory response to the oxygen debt and metabolic demands accumulated during exertion. Notably, the first 10 seconds after exercise marked the most substantial rise in respiratory parameters.

Relative VO_2 (ml/min/kg) and relative VCO_2 (ml/min/kg) also increased rapidly, with relative VCO_2 rising at a faster rate, leading to a slight elevation in the respiratory exchange ratio (RER). Additionally, Vital Capacity (VC) showed a decreasing trend compared to post-warm-up values, potentially indicating transient respiratory fatigue. In contrast, most other respiratory indices showed an upward trend when compared to pre-test values, reflecting the body's acute physiological response to submaximal exertion (Powers & Howley, 2018).

Ten minutes after completing exercise in the submaximal capacity zone, the athletes' respiratory function characteristics had largely returned to pre-exercise levels. Notably, some parameters even surpassed baseline values, suggesting enhanced recovery possibly influenced by effective warm-up and training adaptations (Powers & Howley, 2018).

In comparing the four sports examined in this study, athletics, table tennis, shooting, and Pencak Silat, distinct differences were observed in the dynamics of respiratory function recovery before, during, and after submaximal exercise. Athletes from athletics and Pencak Silat demonstrated more favourable respiratory recovery patterns compared to those in table tennis and shooting. This may reflect the higher cardiorespiratory demands and training adaptations associated with endurance- and combat-based sports (Powers & Howley, 2018).

The current findings are consistent with previous studies that have examined respiratory recovery patterns before, during, and after submaximal exercise. Similar to earlier research, this study observed an initial decline or stabilization in respiratory rate during exercise, followed by a rapid increase immediately after exertion, and a gradual return to baseline levels during the recovery phase. These patterns reflect the typical physiological response to submaximal workloads, where ventilation is closely regulated to meet metabolic demands and subsequently adjusted to repay the oxygen debt post-exercise (Powers & Howley, 2018; Wilmore, Costill, & Kenney, 2015).

Author Contributions

All author contributed equally in this study.

Funding

No research funding for current research.

Acknowledgments

The authors express their gratitude to the participants for their outstanding efforts and cooperation during the data collection period.

Ethical Approval

This study received ethical clearance from the Ethics Committee of Bac Ninh University of Physical Education and Sports, Vietnam.

REFERENCES

- [1] Amann, M., Romer, L. M., Subudhi, A. W., Pegelow, D. F., & Dempsey, J. A. (2007). Severity of arterial hypoxemia affects the relative contributions of peripheral muscle fatigue to exercise performance. *Journal of Applied Physiology*, 101(4), 119-120. <https://doi.org/10.1152/jappphysiol.00259.2007>
- [2] Bentley, D. J., Newell, J., & Bishop, D. (2007). Incremental exercise test design and analysis: Implications for performance diagnostics in endurance athletes. *Sports Medicine*, 37(7), 575–586. <https://doi.org/10.2165/00007256-200737070-00002>
- [3] Binder, R. K., Wonisch, M., Corra, U., Cohen-Solal, A., Vanhees, L., Saner, H., & Schmid, J. P. (2008). Methodological approach to the first and second lactate threshold in incremental cardiopulmonary exercise testing. *European Journal of Cardiovascular Prevention & Rehabilitation*, 15(6), 726–734. <https://doi.org/10.1097/HJR.0b013e328304f4c8>
- [4] Borresen, J., & Lambert, M. I. (2009). The quantification of training load, the training response and the effect on performance. *Sports Medicine*, 39(9), 779–795. <https://doi.org/10.2165/11317780-000000000-00000>
- [5] Gattinoni, L., Tonetti, T., Quintel, M., & Busana, M. (2020). Principles of mechanical ventilation in the context of COVID-19 and its impact on respiratory recovery. *Critical Care*, 24(1), 561. <https://doi.org/10.1186/s13054-020-03279-0>.
- [6] Issurin, V. B. (2010). New horizons for the methodology and physiology of training periodization. *Sports Medicine*, 40(3), 189–206. <https://doi.org/10.2165/11319770-000000000-00000>
- [7] Macfarlane, D. J., & Wong, P. (2012). Validity, reliability and stability of the portable Cortex Metamax 3B gas analysis system. *European Journal of Applied Physiology*, 112(7), 2539–2547. <https://doi.org/10.1007/s00421-011-2235-5>
- [8] McArdle, W. D., Katch, F. I., & Katch, V. L. (2015). *Exercise physiology: Nutrition, energy, and human performance* (8th ed.). Wolters Kluwer Health.
- [9] Nguyen, T. V., Le, Q. T., & Pham, H. D. (2016). Reference standards for respiratory function in Vietnamese athletes. *Vietnam Sports Science Journal*, 32(4), 45–52.
- [10] Powers, S. K., & Howley, E. T. (2018). *Exercise Physiology: Theory and Application to Fitness and Performance* (10th ed.). McGraw-Hill Education.
- [11] Wilmore, J. H., Costill, D. L., & Kenney, W. L. (2008). *Physiology of sport and exercise* (4th ed.). Human Kinetics.