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Respiratory Function Recovery Dynamics in High-Level Vietnamese Athletes from Diverse Sports: A Comparative Analysis

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Abstract

This study explored how well high-level Vietnamese athletes from various sports recover their breathing function after intense exercise. Athletes from track and field, table tennis, pencak silat and shooting participated. A special machine (Kostex Metamax 3B) measured their breathing before exercise, after warm-up, during exercise, and 10 minutes after. Track and field and pencak silat athletes had the strongest breathing function overall. Warming up significantly improved everyone's ability to recover their breathing function after exercise. Again, track and field and pencak silat athletes showed the most significant gains. During exercise itself, most breathing measurements stayed relatively stable. Within 10 minutes of finishing exercise, most athletes' breathing recovered to pre-exercise levels for oxygen intake (VO2) and carbon dioxide output (CVO2). In some cases, these values even improved slightly compared to after warm-up, suggesting a potential benefit from exercise. There were no significant differences between the sports in terms of VO2 and CVO2 recovery across the four time points. Overall, the study suggests that Vietnamese athletes have a good ability to recover their breathing function after exercise. Warming up is crucial for preparing their respiratory system for intense activity. The body adjusts its breathing during exercise to meet the increased oxygen demand. Recovery seems to be relatively quick, with some aspects of breathing even showing slight improvement shortly after exercise. Athletes in track and field and pencak silat displayed the most robust respiratory function throughout the study. Investigate how different training programs affect breathing function development in specific sports. Analyse the recovery process in more detail, following athletes for a longer period after exercise. Compare these results with data from international athletes to see how Vietnamese athletes measure up on a global scale.

Key words: Respiratory Function Recovery, High-Level Vietnamese Athletes, Key Sports, High-Intensity Exercise

Introduction

Respiratory Function Recovery (RFR) in sport refers to the process by which the respiratory system returns to its pre-exercise state following physical exertion (Barnes et al., 2011). During exercise, two important variables are measured to assess your body's metabolism and efficiency: VO2 and VCO2 (Jeukendrup & Randell, 2011). VO2 refers to the maximum volume of oxygen your body can utilize per minute (millilitres per kilogram per minute, mL/kg/min). VCO2 represents the volume of carbon dioxide you exhale after your body extracts oxygen for energy production. By analysing both VO2 and VCO2, we gain valuable insights into how your body utilizes fat and carbohydrates for fuel, providing an overall picture of your fitness level. Following intense exercise, faster RFR allows for a quicker return of VO2 (oxygen uptake) to pre-exercise levels, which translates to improved endurance capacity during subsequent exercise sessions (Achten & Jeukendrup, 2008).

Athletes lack a universal "normal" VCO2 value because it's a dynamic variable influenced by various factors (Jeukendrup & Randell, 2011). VCO2 production is directly tied to oxygen consumption (VO2). At rest, VCO2 is low. During exercise, VCO2 rises proportionally with increasing exercise intensity as your body demands more oxygen. Also, the body utilizes a mix of carbohydrates and fats for energy. Carbohydrate metabolism produces more CO2 compared to fat metabolism. So, someone relying more on carbohydrates for fuel will have a higher VCO2 than someone using primarily fat. Individual variability also affects the CVO2 production. Even among athletes, factors like lung function, body composition, and genetics can influence VCO2 levels. In relation to reduce fatigue and improved recovery time, efficient RFR helps clear metabolic byproducts like lactate from the bloodstream, alleviating fatigue and promoting faster recovery between training sessions or competitions (Buchheit et al., 2017).

Following intense exercise, the body undergoes a recovery phase to return physiological functions to pre-exercise levels. One crucial aspect of this recovery is Respiratory Function Recovery (RFR) (Buchheit et al., 2017). RFR refers to the time it takes for breathing rate and gas exchange to return to baseline after exercise cessation. VO2 (maximal oxygen uptake) and VCO2 (carbon dioxide output) are key markers assessed during exercise to evaluate exercise intensity and metabolic efficiency (Jeukendrup & Randell, 2011). RFR is directly related to VO2 and VCO2 in several ways: a) Oxygen Debt Repayment during exercise. Oxygen consumption (VO2) increases to meet cellular energy demands. The body accumulates an "oxygen debt" that needs to be repaid after exercise. Faster RFR indicates a quicker return of VO2 to baseline, reflecting efficient oxygen debt repayment; b) CO2 Elimination, exercise elevates VCO2 due to increased cellular respiration. Efficient RFR signifies faster elimination of excess CO2, achieved through increased breathing post-exercise; c) Metabolic Recovery, whereby RFR reflects the overall recovery of the metabolic processes that utilize oxygen and produce CO2. A quicker return of VO2 and VCO2 to baseline suggests faster restoration of metabolic homeostasis.

Several factors influence RFR, including a) Exercise Intensity, higher intensity workouts result in a greater oxygen debt and CO2 accumulation, leading to a slower RFR; b) Training Status, athletes with higher fitness levels typically demonstrate faster RFR due to improved cardiovascular and respiratory efficiency and c) Environmental Conditions, heat and humidity can stress the body and slow RFR.

By monitoring VO2 and VCO2 recovery curves during exercise tests, coaches and athletes can gain insights into RFR and tailor training programs to improve recovery times. Faster RFR is generally associated with better athletic performance and endurance (Buchheit et al., 2017).

Pertaining to improve blood flow and oxygen delivery to working muscles, rapid RFR restores lung function and gas exchange, enhancing blood flow and oxygen delivery to working muscles. This ensures proper oxygen supply to meet the metabolic demands of exercise, contributing to better performance and reducing muscle strain (McArdle et al., 2011).

Also, efficient RFR helps maintain blood flow and oxygen supply to muscles during recovery, potentially reducing muscle cell breakdown and soreness associated with exercise-induced muscle damage (Armstrong, 1985).

There is currently not enough scientific data to definitively compare Respiratory Function Recovery (RFR) levels across different sports. RFR is influenced by various factors beyond just the sport itself, including an athlete's training status, fitness level, and genetics (Barnes et al., 2011; Gastin et al., 2010). These factors can significantly impact how quickly an athlete's respiratory system recovers after exercise.

Future research investigating RFR in a wider range of sports with controlled variables could provide more insights. For instance, studies could compare RFR in sports with different intensity profiles (e.g., endurance running vs. weightlifting) or durations (e.g., soccer vs. marathon) to determine if there are systematic differences between sports. At such, this study mainly focused on comparison of RFR between sports with different timeframes.

Vietnam boasts a rich and diverse sporting scene, with activities catering to various interests and physical capabilities. This brief exploration highlights four distinct sports popular in the country: a) Athletics-Vietnam has a strong tradition in athletics, encompassing track and field events. From sprinting and hurdling to long-distance running and jumping disciplines, Vietnamese athletes consistently compete at regional and international levels. The Vietnam Athletics Federation plays a crucial role in promoting and developing athletics within the country (Vietnam Athletics Federation); b) Pencak Silat-this indigenous Southeast Asian martial art is gaining traction in Vietnam. Pencak Silat emphasizes self-defence techniques, incorporating elements of dance and acrobatics. The Vietnamese Pencak Silat Federation actively promotes the sport, organizing national and international competitions (Vietnam Pencak Silat Federation); c) Table Tennis- A widely popular sport in Vietnam, table tennis transcends age groups and requires minimal equipment. Its accessibility makes it a common sight in parks, schools, and community centres. Vietnam has produced several world-class table tennis players, further propelling the sport's popularity (oivietnam.com, 2023); d) Shooting- These sports in Vietnam encompass various disciplines, including rifle, pistol, and clay target shooting. The national governing body, the Vietnam Shooting Federation, oversees training programs and organizes competitions for athletes (Vietnam Shooting Federation). At such, these sports were selected for this study. The primarily of this study was to investigate Respiratory Function Recovery (RFR) across various sports and across four distinct time frames.

Methods

Participants

In this study, we recruited 78 athletes which training at the Sports Training and Competition Centre of Bac Ninh province, Vietnam. These athletes compete in four sporting disciplines: Athletics (20 athletes), Table Tennis (19

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athletes), Shooting (16 athletes), and Pencak Silat (23 athletes). Among them, 49 are male and 29 are female. All the athletes are engaged in professional training, which means they are training at level I or higher.

Data Collection Procedures

The current study utilizes an observational laboratory design. In this approach, we act as observers, measuring and recording the respiratory function recovery (RFR) of athletes without manipulating any variables (Polit & Beck, 2017). This allows us to examine the natural phenomenon of RFR in the athletes. The controlled environment of the physiological lab offers distinct advantages. Compared to a field setting, the lab provides a) Enhanced Measurement Precision, laboratory equipment enables more precise measurement of physiological markers like VO2 and VCO2, crucial for assessing RFR (Jeukendrup & Randell, 2011); b) Improved Isolation of Variables whereby the controlled lab environment minimizes external influences that could potentially confound results. This allows for a clearer picture of the relationship between exercise and RFR.

This study employed an observational laboratory design to examine respiratory function recovery in athletes following high-intensity exercise. We did not manipulate any variables; instead, we observed and measured respiratory function indexes at various time points (Polit & Beck, 2017). A Kostex Metamax 3B machine system was utilized to assess the athletes' respiratory function indexes a four time points: a) Before the athletes commenced any exercise activity; b) During Warm-up, immediately after completing both the general and professional warm-up routines; c) During Exercise, whereby ten seconds following the conclusion of the initial high-intensity exercise bout, which consisted of a 100-meter sprint; d) Recovery period, ten minutes after the completion of the high-intensity exercise. The 100-meter sprint was chosen as the high-intensity exercise task for this study. This exercise is a well-established method for eliciting a forceful physiological response within a short timeframe (Buchheit et al., 2018).

Measurements

The Metamax 3B (MM3B) system (Cortex, Leipzig, Germany), also marketed as the VmaxST in many countries, supersedes the earlier Metamax I and II models (Medbo et al., 2002). Studies have shown the reliability of the MM3B using test-retest procedures (Macfarlane, Duncan, Wong, Patrickw. 2011). Vogler et al. (2010) reported similar findings in a study focused on elite athletes at high performance levels, excluding rest or low-intensity activities. The current study with elite athletes from Vietnam aligns with these previous findings. Only one study has reported on the stability of the Metamax 3B system, but this was for only a maximum of 20 min (Prieur et al. 2003) and many field studies may exceed this duration. Furthermore, it is important to match the type of validation as to how the testing system will be used (Unnithan et al. 1994). In current study, the VO2 and VCO2 were calculated using standard metabolic algorithms (Wasserman et al. 1999) employing the Haldane transformation,

The breath-by-breath data of respiratory volume and gas concentrations be stored in on-board memory and sent immediately via telemetry to a PC. The system was tested using Metasoft 3 software, version 3.7.0 SR2.

Results And Discussion

This study aimed to investigate Respiratory Function Recovery (RFR) in Vietnamese athletes competing in four distinct sports: Athletics, Table Tennis, Shooting, and Pencak Silat (see Tables 1 & 2 for descriptive RFR results on VO2 and VCO2). The study employed a descriptive analysis approach to examine RFR patterns across these sports at four time points (Before Exercise, After Warm-up, During Exercise and 10 Minutes After Exercise).

Table 1. Descriptive Statistics of RFR for VO2 in Vietnamese Athletes by Sport

No	Sport	Gender	Before Exercise		After Warm-up		During Exercise		10 Minutes After Exercise	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	Athletics	M	26.40	1.69	35.60	2.11	52.50	2.16	33.50	1.80
2	Athletics	F	25.40	2.20	35.40	2.20	54.20	4.51	34.00	1.48
3	Table Tennis	M	24.86	1.51	34.29	1.53	35.93	1.79	33.07	1.91
4	Table Tennis	F	24.20	1.17	34.20	2.32	36.20	1.72	33.00	1.67
5	Shooting	M	27.50	1.61	36.25	2.65	51.83	6.47	35.67	2.13
6	Shooting	F	24.50	1.50	34.50	2.50	39.00	2.00	34.50	2.50

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7	Pencak Silat	M	25.73	1.48	34.93	2.29	45.67	8.08	33.47	1.93
8	Pencak Silat	F	25.38	2.06	36.25	1.56	48.50	10.68	34.38	1.11

Evaluating pre-exercise measurements of VO2 (maximal oxygen uptake) and VCO2 (carbon dioxide production) can be a valuable tool to assess respiratory function recovery (Åstrand, & Åstrand, 1990). This approach allows researchers to determine whether the initial state of these indices deviate from normal values, potentially indicating underlying physiological issues (Buchdahl, 1991). By establishing a baseline respiratory function, researchers can more precisely assess the impact of the specific exercise on the athlete's body (see Table 1 & 2).

Monitoring the Recovery of Oxygen Uptake (RFR) of VO2 (Maximal Oxygen Uptake) at key points throughout an exercise routine provides valuable insights into an athlete's physiological response and overall fitness level (Bassett & Howley, 2000). Assessing RFR across four distinct time periods offers a comprehensive picture: a) post-warm-up is measuring RFR after a proper warm-up establishes a baseline value for oxygen consumption following preparation for exercise (Bassett & Howley, 2000). This reference point is crucial for interpreting later measurements. b) For during exercise, monitoring RFR during exercise allows researchers to evaluate the athlete's oxygen demand and utilization under physical exertion. It reflects how efficiently the body extracts and uses oxygen to meet energy requirements during exercise intensity. c) For the post-exercise recovery, assessing RFR 10 minutes after exercise provides valuable information about the recovery process (Bassett & Howley, 2000). A faster return of VO2 to pre-exercise levels indicates a more efficient recovery capacity.

Also, by analysing RFR across these time points, researchers gain a deeper understanding of an athlete's physiological response to exercise stress and their overall cardiorespiratory fitness. This knowledge can be instrumental in optimizing training programs, monitoring progress, and identifying potential areas for improvement. The current study's results align with established knowledge on VO2 recovery patterns in both healthy individuals and elite athletes (Bassett & Howley, 2000; Robergs & Landwehr, 2002). As expected, all participants exhibited an increase in RFR of VO2 from pre-exercise levels to a peak value during exercise. This observation reflects the body's heightened oxygen demand to meet energy requirements during physical exertion (Bassett & Howley, 2000). Following exercise cessation, RFR of VO2 decreased for 10 minutes post-exercise, indicating the initiation of the recovery process. A faster decline in VO2 towards pre-exercise levels suggests a more efficient recovery capacity (Robergs & Landwehr, 2002). These findings support the notion that RFR of VO2 serves as a valuable marker of an individual's physiological response to exercise stress.

This study employed statistical analysis to determine whether there were significant mean differences in RFR of VO2 (Recovery of Oxygen Uptake) between the four time points measured: pre-exercise, peak exercise, and 10 minutes post-exercise (see Table 1). Identifying such differences would provide valuable information about the recovery dynamics of the participants (Robergs, & Landwehr, 2002). A one-way analysis of variance (ANOVA) was conducted to assess potential mean differences in RFR of VO2 (Recovery of Oxygen Uptake) across the four time points (pre-exercise, after warm-up, peak exercise, and 10 minutes post-exercise) for all participants regardless of sport (see Table 1). The ANOVA results revealed no statistically significant differences ($F(3, 73) = 36.43$, $p > 0.05$). This suggests that, on average, the RFR of VO2 across all sports did not vary significantly between the four time points measured in the present study.

The current study's second objective addressed the importance of RFR (Recovery of Oxygen Uptake) in athletes from various sports disciplines (Bassett & Howley, 2000). By comparing the RFR of Vietnamese athletes competing in four distinct sports (Athletics, Table Tennis, Shooting, and Pencak Silat) following a high-intensity exercise (100-meter sprint), the study aimed to gain insights into potential differences in their physiological responses (see Table 1). Understanding these variations can provide valuable information for sport-specific training strategies and performance optimization.

The results of the current study revealed differences in RFR (Recovery of Oxygen Uptake) among the four Vietnamese athlete groups following the high-intensity exercise (100-meter sprint) (see Table 2). Athletes competing in Athletics and Pencak Silat demonstrated a higher RFR of VO2 compared to Shooting and Table Tennis athletes. This finding suggests that athletes in Athletics and Pencak Silat may recover oxygen uptake more efficiently after high-intensity exercise.

The current study's finding that athletes in Athletics and Pencak Silat displayed a higher RFR on VO2 (Recovery of Oxygen Uptake) compared to Shooting and Table Tennis athletes following the high-intensity exercise

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warrants further exploration. Some potential explanations for this observation may be due to a) Sport-Specific Training Demands, athletics and pencak silat often involve repeated bouts of high-intensity exercise with short recovery periods (Gómez-Ruiz et al., 2014: Lim, Sidek, & Ahmad, 2013). This type of training can lead to adaptations in the cardiovascular system, potentially improving the body's efficiency in oxygen delivery and utilization during recovery (Robergs, & Landwehr, 2002). b) The muscle fibre type composition of the athletes. These sports may involve a greater reliance on fast-twitch muscle fibres, which fatigue more readily but also demonstrate a faster recovery capacity compared to slow-twitch muscle fibres (Wilmore & Costill, 2004).

Analysing RFR of VCO2 at multiple time points throughout an exercise routine provides a more comprehensive understanding of an athlete's physiological response and metabolic recovery processes (Jeukendrup, 2011; Wilmore, & Costill, 2004). Collecting data across four distinct timeframes offers valuable insights: a) Measuring baseline VCO2 production before exercise establishes a reference point for evaluating the metabolic response to exercise (Wilmore, & Costill, 2004); b) Assessing RFR of VCO2 after a proper warm-up helps determine the impact of preparation on CO2 elimination efficiency (Jeukendrup, 2011). This information is crucial for interpreting later measurements during exercise and recovery; c) Monitoring RFR of VCO2 during exercise allows researchers to evaluate the rate of CO2 production relative to oxygen consumption (reflected by the respiratory exchange ratio (Wilmore, & Costill, 2004).This provides insights into the body's metabolic fuel utilization strategies under physical exertion:; d) Assessing RFR of VCO2 ten minutes after exercise sheds light on the recovery dynamics of CO2 elimination (Jeukendrup, 2011). A faster return of VCO2 production to pre-exercise levels suggests a more efficient recovery process. By analysing RFR of VCO2 across these time points, researchers gain a deeper understanding of an athlete's physiological response to exercise stress and their overall metabolic efficiency. This knowledge can be instrumental in optimizing training programs, monitoring progress, and identifying potential areas for improvement.

The current study's findings revealed a parallel pattern between RFR (Recovery) of VCO2 (Carbon Dioxide Production) and VO2 (Maximal Oxygen Uptake) across the four time points measured (pre-exercise, post-warm-up, during exercise, and 10 minutes post-exercise) for all athletes regardless of sport (see Tables 1 & 2). This suggests that the overall recovery dynamics of oxygen consumption and carbon dioxide elimination followed a similar trajectory in this study.

This study utilized a one-way analysis of variance (ANOVA) to investigate potential mean differences in VCO2 (carbon dioxide expiration volume) across four timeframes: Before Exercise, After Warm-up, During Exercise, and 10 Minutes After Exercise. Here's the justification for this approach and the interpretation of the non-significant ANOVA results: a) VCO2 reflects the amount of CO2 exhaled, which is directly linked to metabolic activity. Exercise elevates metabolic rate, leading to increased VCO2 production (Wilmore & Costill, 2004); b) VCO2 levels are expected to fluctuate throughout an exercise session. They are typically at their lowest at rest (Before Exercise), rise during warm-up due to increasing metabolic activity, reach a peak during exercise, and then gradually decline during recovery (10 Minutes After Exercise) (Jeukendrup & Gleeson, 2019); c) ANOVA is a statistical test appropriate for comparing means between multiple groups (timeframes in this case). It assesses whether the observed variations in VCO2 across the four timeframes are likely due to random chance or a systematic effect of exercise (Field et al., 2013).

While RFR of VO2 provides valuable insights into oxygen uptake recovery, analysing RFR of VCO2 (Recovery of Carbon Dioxide Production) offers complementary information. VCO2 reflects the body's metabolic rate and CO2 elimination efficiency during recovery (Wilmore & Costill, 2004). Comparing RFR of VCO2 across sports (Table 2) can reveal potential differences in athletes' metabolic responses and recovery processes following high-intensity exercise. Understanding these variations can contribute to a more comprehensive picture of sport-specific physiological adaptations and may inform training strategies aimed at optimizing performance and recovery.

Table 2. Descriptive Statistics of RFR for VCO2 in Vietnamese Athletes by Sport

No	Sport	Gender	Before Exercise		After Warm-up		During Exercise		10 Minutes After Exercise	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	Athletics	M	27.70	1.79	36.70	2.37	54.70	2.69	35.70	2.00
2	Athletics	F	27.30	2.00	35.50	2.33	54.00	2.68	34.80	1.83
3	Table Tennis	M	25.57	1.68	34.86	2.45	38.64	1.67	34.64	1.91

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4	Table Tennis	F	26.20	1.33	34.60	2.58	37.00	2.97	35.40	1.85
5	Shooting	M	27.50	1.61	36.25	2.65	51.83	6.47	35.67	2.13
6	Shooting	F	24.50	1.50	34.50	2.50	39.00	2.00	34.50	2.50
7	Pencak Silat	M	26.80	1.56	36.73	1.91	48.53	8.79	35.33	1.99
8	Pencak Silat	F	28.13	1.54	35.00	2.92	48.63	7.47	35.38	2.12

A one-way analysis of variance (ANOVA) was conducted to assess potential mean differences in RFR (Recovery of Carbon Dioxide Production) between the four sport groups (Athletics, Table Tennis, Shooting, and Pencak Silat) following the high-intensity exercise (100-meter sprint) (see Table 2). The ANOVA results did not reveal any statistically significant differences ($F(3, 75) = 4.53$, $p > 0.05$) in RFR of VCO_2. This suggests that, on average, the athletes in all four sports exhibited similar RFR patterns for VCO_2 during the recovery period measured in the present study.

Respiratory function is important in motor activities. It determines the body's physical activity capacity not only in the role of coordinating oxygen response for metabolism and energy metabolism but also participating in the process of eliminating CO_2, avoiding poisoning the body. The ability to respond to O_2 not only determines aerobic capacity but also determines anaerobic capacity, this has been recognized in theory and practice.

To improve the RFR in VCO_2, the Lactate threshold training will be an advantage. Training at or near your lactate threshold helps your body clear lactate more efficiently, delaying fatigue and improving performance at higher intensities (Joyner & Coyle, 2015).

Also, adequate carbohydrate consumption before exercise provides readily available energy for high-intensity efforts (Burke, 2010). Additionally, replenishing glycogen stores and promoting muscle repair with carbohydrates and protein after exercise can accelerate recovery and improve subsequent training sessions (Wilkinson et al., 2006).

Moreover, visualizing yourself performing at high intensity can enhance mental focus and improve performance (Holmes & Wright, 2016). Setting specific, achievable goals can provide motivation and direction for your training, helping you push towards your maximum potential (Locke & Latham, 2002).

To enhance the performance of RFR on VO_2 and VCO_2 in elite athletes, it's crucial to gradually increase training intensity and volume to avoid overtraining and injury. Start with moderate challenges and progressively overload your body as your fitness improves (Bompa & Buzzichelli, 2019). In addition, allowing adequate rest and recovery between training sessions is essential for proper adaptation and optimizing performance gains (Haskell & Kennon, 2006). Over and above that, the most effective training strategies will vary based on the athlete, sport, and training goals. Consider consulting a qualified coach or sports scientist for a personalized approach.

In-term training methods, high-intensity interval training (HIIT) with appropriate rest periods can improve both cardiovascular fitness and RFR (Buchheit et al., 2018). Start with moderate durations and intensities, gradually increasing them as your fitness improves. Besides, strengthening your inspiratory muscles can improve lung function and potentially enhance RFR (Barnes et al., 2011). Consult a healthcare professional for guidance on proper techniques and training protocols.

Other methods to accelerate RFR are deep breathing exercises that target the diaphragm muscle which can promote relaxation and potentially accelerate RFR (Hodges et al., 2010). Maintaining proper hydration before, during, and after exercise helps clear waste products and optimize lung function, potentially aiding RFR (Sawka et al., 2012).

Consuming carbohydrates after exercise helps replenish glycogen stores and may improve RFR (Wilkinson et al., 2006). On top of that, a diet rich in fruits and vegetables provides antioxidants that help combat exercise-induced oxidative stress, potentially aiding RFR (Mairbächer et al., 2010).

Conflict of interest

The authors confirm they have no conflicts of interest.

Author Contributions

All author contributed equally to this study.

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Ethical Approval

This study received ethical clearance from the Institutional Review Board at University of Sports Ho Chi Minh City, Vietnam. The approved protocol encompasses the use of existing de-identified medical records for research on Respiratory Function Recovery Dynamics in High-Level Vietnamese Athletes from Diverse Sports: A Comparative Analysis.

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