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Integration Between Core Stability And Respiratory Efficiency In High- Performance Swimmers: A Narrative Review

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Abstract:
The present study aims to synthesize, through a narrative literature review, the interaction between core stability and the respiratory system in high-performance swimmers. The review was conducted in a descriptive manner, initially addressing the profile of elite swimmers and the biomechanical demands of the sport. Subsequently, the anatomical foundations of the core and the principles of respiratory function are presented, including their adaptations to the aquatic environment. Finally, the interaction between central stability and ventilatory efficiency is discussed. Overall, the literature indicates that central stability contributes to improved hydrodynamic alignment, force transfer, and technical stroke mechanics, while respiratory adaptations resulting from training enhance ventilatory efficiency and reduce the energetic cost of breathing. When combined, these factors act synergistically to optimize movement economy and enhance performance in high-intensity events. Thus, it is concluded that the integration between core stability and respiratory efficiency is essential for optimizing body alignment, movement economy, and performance in high-level swimmers, despite the variations observed across protocols and study populations.
Key Word: *Swimming, Core, Respiratory Function; Sports Performance; Ventilatory Efficiency.*

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I. Introduction

Swimming is a sport characterized by high physiological, technical, and biomechanical demands, in which minimal differences in time can determine competitive outcomes (KWOK WY, et al., 2021). In sprint events, variations as small as 0.01 s and 0.02 s defined the first two positions in the men's and women's 50 m freestyle finals, respectively, at the Rio 2016 Olympic Games (International Olympic Committee, 2016). Performance in swimming is determined by efficiency in the start, stroke, and turn phases, and improvements in any of these components can potentially optimize the overall race time (TRINIDAD A, et al., 2022).

In the context of high-performance sport, core stability represents an essential biomechanical component for technical and respiratory efficiency, as postural control and whole-body coordination are critical for hydrodynamic alignment and propulsion optimization. This stability supports efficient force transfer between limbs, reduces drag, and enhances the mechanical efficiency of the stroke (RODRÍGUEZ S, et al., 2025). Core strength refers to the ability of the core muscles to generate and sustain force through coordinated contractions and the regulation of intra-abdominal pressure, while stability relies on the integrated action of active and passive stabilizers of the lumbopelvic region in maintaining alignment and postural control during static and dynamic tasks (LUO S, et al., 2022).

Studies indicate that specific core training improves neuromuscular strength, motor coordination, and swimming time in adolescent and adult swimmers, with adaptations observed both in land-based programs and in combined training protocols (CUNHA M, et al., 2019; KHIYAMI A, et al., 2022). Parallel to this, competitive swimmers develop distinct ventilatory and pulmonary adaptations in response to prolonged aquatic training and the respiratory demands of the sport. The continuous stimulus imposed by thoracic immersion, together with controlled breathing during stroke cycles, leads to increases in forced vital capacity and forced expiratory volume in one second (McCONNELL A, 2013).

The inspiratory resistance generated by hydrostatic pressure promotes strengthening of the respiratory muscles, resulting in higher maximal inspiratory and expiratory pressures and more efficient ventilation during exertion. The ventilatory pattern is characterized by deep inspirations and controlled, movement-synchronized expirations, which optimize gas exchange and reduce the energetic cost of breathing (PAIVINEN M, et al., 2021). Additionally, inspiratory muscle training has been shown to improve respiratory strength, pulmonary function, and the perception of dyspnea, producing positive effects on performance (CUNHA M, et al., 2019).

Emerging evidence suggests a functional relationship between core stability and respiratory efficiency. The synergy between trunk musculature and the diaphragm is essential for maintaining intra-abdominal pressure and optimizing respiratory mechanics (CAVAGGIONI L, et al., 2015). Exercises targeting abdominal strengthening and diaphragmatic breathing may reduce drag during gliding and improve ventilatory patterns while swimming (MARUYAMA Y AND YANAI T, 2015).

However, the interaction between central stability and respiratory function in elite swimmers remains an understudied area, with important gaps concerning both the underlying physiological mechanisms and the practical applicability of training programs. In this context, it becomes pertinent to integrate the available knowledge regarding the role of the core and respiratory function in high-performance swimming. Accordingly, the present study aims to conduct a narrative literature review on the interaction between core stability and the respiratory system in high-performance swimmers.

II. High-Performance Swimmers

High-performance swimmers are distinguished by their high level of training commitment and by their participation in national and international competitions. Their training programs are intensive and include aquatic sessions combined with resistance training, strength development, flexibility work, cardiovascular conditioning, and technical refinement. In addition to mastering sport-specific skills—such as stroke technique, turns, and starts— these athletes must maintain healthy lifestyle habits, including adequate nutrition, hydration, and recovery strategies that support performance and reduce injury risk (OKADA T, et al., 2011).

The competitive profile of these swimmers encompasses participation in a range of events, from short-distance races in Olympic pools to open-water marathons, consistently aiming for personal bests, national rankings, and notable results in major international competitions such as the Pan American Games and the Olympic Games. Achieving this level of performance requires guidance from specialized coaches who design individualized physical and psychological training plans (OKADA T, et al., 2011). Among swimming strokes, the front crawl stands out as the most widely used in competitions and scientific research, characterized by alternating movements of the arms and legs in a prone position (Figure 1) (KWOK YU, et al., 2021).

Figure 1 – Front crawl stroke
Source: McLeod (2010).

According to Nasirzade A, et al. (2014), core stability is a determining factor in integrating the actions of the upper and lower limbs and providing adequate support during swimming. The abdominal musculature functions almost continuously, supplying postural support and promoting efficiency in aquatic displacement by contributing to propulsion and reducing hydrodynamic drag.

Respiratory function represents another essential component, as swimmers must control breathing to optimize oxygen delivery and sustain endurance throughout the race. Core musculature contributes to trunk stabilization by providing a solid base for the respiratory muscles, such that strengthening this region enhances ventilatory control—particularly during turns and body-rolling movements—and consequently promotes improved posture, greater lung expansion, and more effective air intake (OKADA T, 2011; MURLASITS Z, et al., 2023).

Therefore, the literature indicates that both core strengthening and respiratory function are directly related to mechanical efficiency and performance in high-level swimmers. These findings reinforce the need to integrate functional training strategies targeting the trunk with interventions that optimize respiratory function, establishing both components as fundamental pillars in the preparation of these athletes (LOMAX M, et al., 2019; KWOK WY, et al., 2025; RODRÍGUEZ S, et al., 2025).

III. Trunk Stabilizing Muscles

The stabilizing musculature of the trunk plays a fundamental role in protecting the structures of the vertebral column, maintaining postural alignment, and controlling segmental mobility. When these muscles become hypotonic or are recruited inadequately—whether due to disuse, poor habitual posture, or biomechanical imbalances—trunk stability is compromised, increasing susceptibility to mechanical overload, pain, and functional alterations (LU ML, et al., 2015).

Commonly referred to as the *core*, the group of muscles located in the lumbopelvic and abdominal region integrates the actions of the upper and lower limbs, ensuring bodily balance and efficient transmission of motor force during daily and sports-related activities. This group includes the rectus abdominis, the internal and external obliques, the transversus abdominis, the pelvic floor muscles, the multifidus, the erector spinae muscles (iliocostalis, longissimus, and spinalis), the quadratus lumborum, and accessory muscles such as the gluteals, adductors, and the iliopsoas (LIEBMAN HL, 2014).

The anterolateral abdominal musculature—composed of the rectus abdominis, pyramidalis, internal and external obliques, and transversus abdominis—performs functions that extend beyond abdominal protection (Figure 2). The rectus abdominis is responsible for trunk flexion, while the pyramidalis has a minor structural role. The transversus abdominis acts as a natural stabilizing belt, and the oblique muscles contribute to trunk rotation and lateral flexion, while also assisting in the maintenance of intra-abdominal pressure and dynamic spinal stability (LIEBMAN HL, 2014).

The erector spinae muscles (iliocostalis, longissimus, and spinalis) and the multifidus are essential for spinal extension, rotation, and segmental stability. The iliocostalis supports upright posture, the longissimus contributes to lateral flexion, rotation, and respiratory mechanics, and the spinalis provides fine stabilizing control of vertebral segments. The quadratus lumborum assists in extension, lateral flexion, and functional stabilization of the trunk (LIEBMAN HL, 2014).

Core instability is directly associated with the occurrence of low back pain, a condition that ranks among the most prevalent musculoskeletal complaints. Weakness or delayed activation of these muscles overloads intervertebral discs, facet joints, and ligaments, contributing to the development of chronic pain and associated dysfunctions. Strengthening programs have been shown to improve lumbar stability, optimize muscle activation patterns, and reduce painful episodes (STANDAERT CJ, et al., 2008).

IV. Trunk Stabilization In Front Crawl Swimming

From a functional perspective, trunk stabilization plays a decisive role in sports that require whole-body coordination, such as swimming. In the front crawl, efficient activation of the core—which involves the abdominal, lumbar, pelvic, and gluteal musculature—promotes hydrodynamic alignment, reduces drag, and enhances force transfer between the upper and lower limbs (NASIRZADE A, et al., 2014). McGill (2003) emphasizes that no single muscle predominates in this process; rather, stability results from the synergistic action of multiple muscle groups, whose coordinated function generates appropriate stiffness across multiple degrees of freedom.

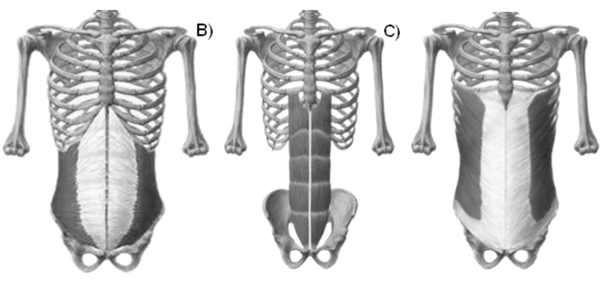

Figure 2 – A) Transversus abdominis muscle; B) Rectus abdominis and pyramidalis muscles; C) Internal and external oblique muscles.
Source: https://quizlet.com/py/308134021/anatomia-p1-22-flash-cards/

The abdominal musculature — particularly the rectus abdominis, oblique muscles, and transversus abdominis — supports the trunk, protects the visceral organs, assists in respiration, stabilizes the pelvis, and coordinates trunk–limb interactions, thereby promoting fluid movement. The gluteal and pelvic muscles contribute to the proximal stability required for effective distal movements of the arms and legs. The lumbar and dorsal musculature, composed of the erector spinae, multifidus, and latissimus dorsi, is activated during the front crawl. While the erector spinae and multifidus stabilize spinal segments and control posture, the latissimus dorsi acts in conjunction with the trapezium and rhomboids to generate upper-limb traction, thereby enhancing propulsion in the water (SECCHI LLB et al., 2010; NASIRZADE A et al., 2014).

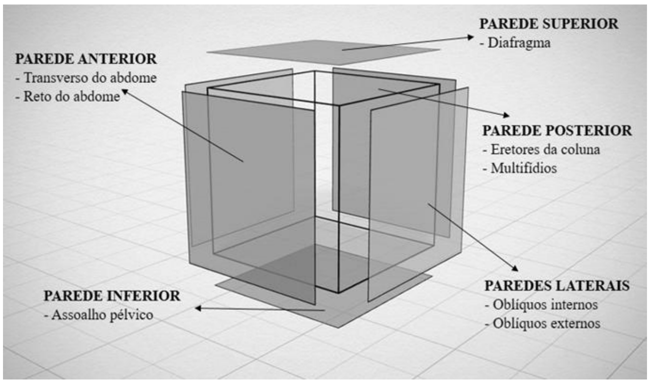

Figure 3 – Schematic illustration showing the boundaries of the core based on trunk musculature
Source**:** Author, 2023.

In parallel, the shoulder muscles — particularly the deltoid and the rotator cuff complex (subscapularis, supraspinatus, infraspinatus, and teres minor) — play fundamental stabilizing and mobilizing roles. This musculature enables powerful execution of the pull phase and controlled movement during the recovery phase, preventing joint overload and reducing the risk of overuse injuries. In the arm, the biceps and triceps alternate between elbow flexion and extension, ensuring continuity throughout the stroke cycle (MAGLISCHO EW, 2010). Although lower-limb movements in the front crawl are less intense than in other styles, such as the breaststroke, they still contribute significantly. The quadriceps, hamstrings, and triceps surae assist in maintaining body balance, sustaining a horizontal posture, and preserving kick rhythm, thereby enhancing whole-body stability in the water. This coordinated action between the lower limbs and trunk musculature reinforces the importance of integrating proximal stability with distal mobility (MAGLISCHO EW, 2010).

Recent evidence indicates that non-expert swimmers with greater trunk inclination, or postural misalignment, exhibit reduced knee range of motion, decreased kicking force, and diminished lower-limb propulsion. Such alterations directly affect body posture maintenance and increase the demand for proximal trunk stability to compensate for these deficits (COSTA MJ, et al., 2025).

Thus, front crawl swimming is characterized by the integrated recruitment of abdominal, lumbar, pelvic, dorsal, upper-limb, and lower-limb muscles. Efficiency and performance depend not solely on isolated muscular power but also on the coordination, endurance, and synchrony across different muscle groups, which underscores the role of the core as a central link between body segments (Figure 5). This muscular interaction is also essential for preventing overload-related injuries and sustaining performance in high-level athletes (MAGLISCHO EW, 2010; NASIRZADE A et al., 2014).

Accordingly, the trunk-stabilizing muscles should be regarded not only as structural support elements but also as active components of motor control, integrating structural protection, functional capacity, and athletic performance. Strengthening these muscles represents an essential strategy both in the rehabilitation of lumbar dysfunctions and in the optimization of sports performance (RODRÍGUEZ S, et al., 2025).

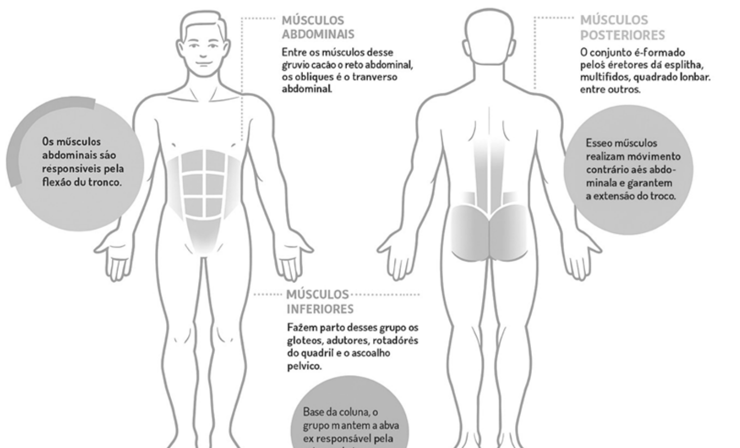

Figure 5 – Core muscles
Source: https://www.uol.com.br/vivabem/especiais/core/

V. Respiratory Function In High-Performance Swimmers

The respiratory system is composed of the lungs, the central organs of gas exchange, and the structures of the thoracic and abdominal walls that support ventilatory mechanics. Its primary function is to generate airflow through coordinated displacement of the thoracic and abdominal compartments, thereby maintaining effective gas exchange. Breathing is a mechanical, automatic, uninterrupted, and synchronized process regulated by the respiratory center located in the medulla (De TROYER A and BORIEK AM, 2011).

Airflow into and out of the terminal lung units results from the contraction and relaxation of the diaphragm and abdominal muscles, along with movements of the rib cage and abdomen. The inspiratory phase is characterized by thoracic expansion due to a drop in intrathoracic pressure below atmospheric pressure. The primary respiratory muscles involved in this process are the diaphragm and external intercostals, whereas the expiratory phase is passive at rest (Figure 6) (PEATE I, 2021).

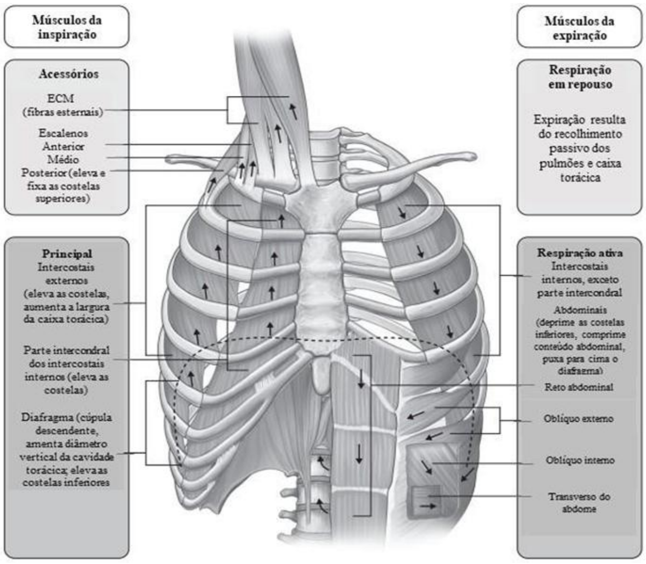

Figure 6 – Schematic illustration of the respiratory muscles
Source: McConnell (2013).

Nasal patency represents an essential physiological component of the adult respiratory pattern. Nasal breathing is considered the physiological standard throughout life, and the nasal cavity performs filtration, warming, and humidification of inspired air, preparing it for efficient pulmonary oxygenation (VERON HL et al., 2016). It also stimulates endogenous nitric oxide production, promoting vasodilation and bronchodilation, which improves pulmonary blood flow distribution and reduces ventilatory load (NICOLÒ A, et al., 2023). Recent studies demonstrate that nasal breathing during submaximal exercise increases ventilatory efficiency by reducing respiratory rate, increasing tidal volume, and lowering the ventilation-to-CO_2 ratio compared to oral breathing (ESER P, et al., 2024).

The respiratory system ensures the transport of oxygen to the alveolar–capillary barrier, enabling adequate gas exchange to meet cellular demands. The airways progressively narrow toward the alveoli, increasing resistance to airflow, while the alveoli maintain structural integrity to withstand mechanical forces and optimize gas diffusion (WEST JB, 2015). In high-performance swimming, respiratory function is challenged at its maximal capacity and becomes a determining factor for achieving sustainable competitive performance (LIU S, et al., 2025b). Respiratory muscle strength depends on the biomechanical and physiological relationships of length–tension, force–velocity, and contractile integrity. The effectiveness of contraction is also influenced by lung volume and body position during effort. Recent evidence indicates that, in athletes, respiratory muscle strength plays a substantial role in determining maximal oxygen consumption, suggesting that efficient respiratory muscles may modulate athletic performance (De LICEOĞLU G et al., 2024).

Although greater respiratory muscle strength and increased lung volumes may enhance performance in front crawl swimming, several additional factors can influence outcomes, including lung structure, genetic predisposition, and training level. Studies indicate that forced expiratory volume in one second (FEV_1) shows a positive correlation with age and years of practice, reflecting functional adaptations. In young swimmers, vital capacity is higher than that of non-athletic children, suggesting that early training promotes both anatomical and functional lung growth, associated with more efficient breathing patterns and greater inspiratory strength (ROCHAT I, et al., 2022).

During swimming, breathing synchronizes with the motor cycle and requires adequate inspiratory strength (Figure 7). Swimmers exhibit increased tidal volume due to ventilatory constraints imposed by thoracic hydrostatic pressure and by the prone or supine position, which promote hemodynamic redistribution and reduce pulmonary compliance, thereby increasing the mechanical and metabolic demands placed on the respiratory muscles (MAGEL JR and FAULKNER JA, 1967; GUYATT AR, et al., 1965). The unilateral breathing pattern characteristic of front crawl can also lead to biomechanical asymmetries that affect trajectory, propulsive forces, and movement efficiency (COHEN RCZ, et al., 2020).

VI. Interaction Between Core Stability And Respiratory Function In High-Performance Swimmers

The analysis presented in this review indicates that the interaction between ventilatory adaptations and core stability operates synergistically to optimize performance in high-level swimmers. At the pulmonary level, prolonged aquatic training promotes functional modifications that include increased lung volumes, enhanced respiratory musculature, and the establishment of a more efficient ventilatory cycle (Armour J et al., 1993). In parallel, the core functions as a central hub for force transmission and lumbopelvic stabilization, playing a crucial role in maintaining coherence between stroke mechanics, propulsion, and hydrodynamic postural control (WESTON M, et al., 2015).

A recently published meta-analysis identified that interventions targeting the strengthening of the body's central region produce meaningful improvements in 50 m freestyle performance, with average reductions close to 1 second in final race time. Another study conducted with young swimmers reported that six weeks of complementary core-focused training resulted in an average reduction of 1.4 seconds in 50 m front crawl performance, corresponding to an improvement of approximately 3.47% compared to the control group (WESTON M et al., 2015). Overall, these findings demonstrate that the core does not serve merely as auxiliary musculature but plays a decisive role in effective energy transfer between limbs and in reducing drag and speed loss.

The integration of ventilatory and central domains suggests that respiratory efficiency in athletes is not limited to increased ventilation or isolated improvements in pulmonary function, but instead depends on how effectively ventilation operates within a stable and hydrodynamic body system. In other words, even with elevated lung volumes or strengthened respiratory muscles, if the swimmer's body alignment is unstable or the core is insufficiently effective in maintaining force transmission, maximal performance gains may be compromised (PÄIVINEN M, et al., 2021). This implies that intervention programs for high-performance swimmers should incorporate combined training that simultaneously addresses respiratory musculature, core stabilization, and stroke technique (CUNHA M, et al., 2019; LIU S, et al., 2025b).

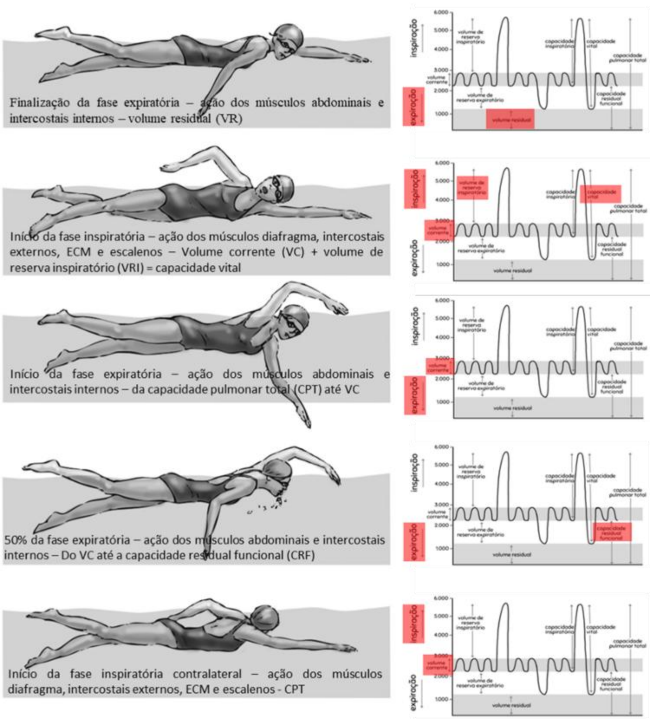

Figure 7 – Schematic illustration of respiration
Source: Adapted from Guyton and Hall (2017).

Inspiratory muscle training using resistance-based devices should be incorporated as a complement to aquatic training, with intensity progressing between 50% and 80% of maximum inspiratory pressure over a period of 6 to 8 weeks. This type of intervention increases respiratory muscle strength, improves ventilatory efficiency, and reduces the perception of dyspnea, directly enhancing competitive performance (Liu S et al., 2025b). Complementarily, core stability training should be structured into 30-to 60-minute sessions performed two to three times per week for at least 6 to 8 weeks, with emphasis on lumbopelvic control, integration between limbs and trunk, and coordination of inspiratory and expiratory respiratory contraction patterns (KARPIŃSKI J, et al., 2020; LIU S, et al., 2025a).

Optimal periodization should include integrated training blocks combining land-based exercises, respiratory muscle strengthening, neuromotor enhancement, and sport-specific aquatic practice, thereby synchronizing ventilatory and postural adaptations with the biomechanical demands of swimming movements. A block-based structure allows the overload applied to the inspiratory muscles and the lumbopelvic region to be periodized in a way that maximizes the neuromuscular adaptation window before the introduction of aquatic technical load (LIU S, et al., 2025b). An integrated program design with careful definition of frequency, duration, and sequencing of stimuli reduces adaptive fragmentation and enhances the transfer of land-based gains to objective improvements in mechanical efficiency, ventilatory economy, and hydrodynamic performance during swimming (LIU S, et al., 2025a).

From this perspective, physiotherapists and strength and conditioning professionals should adopt combined approaches grounded in principles of integrated periodization, enabling physiological and neuromuscular adaptations to be translated into measurable improvements in race time, propulsive power, and mechanical efficiency in the water. This approach also enhances mechanical efficiency by reducing motor compensations, minimizing energetic cost, and increasing effort sustainability—factors directly associated with competitive performance in high-level swimmers. Studies show that programs structured in this manner lead to measurable improvements in race time, stroke efficiency, and swimming-specific ventilatory capacity (KARAPOLAT S and DAĞLIOĞLU Ö, 2020; KHIYAMI A, et al., 2022).

Despite these promising practical implications, this review presents limitations that must be considered when interpreting its findings. Many of the studies included involve participants with varying levels of performance, which reduces the venerability of the results to elite swimmers. Furthermore, substantial heterogeneity exists among training protocols targeting both the core and respiratory musculature, with variations in duration, frequency, intensity, and sample characteristics, making direct comparisons and high-level meta-analyses challenging. In many studies, either the core or the respiratory system was evaluated in isolation, without joint assessment or examination of their interaction in swimmers, limiting the ability to infer the synergy between these variables.

Nonetheless, despite these limitations, the present study provides relevant contributions by integrating two dimensions traditionally examined separately, offering a more comprehensive understanding of performance in high-level swimming. The review methodology enabled the synthesis of meaningful evidence, including controlled trials and meta-analyses that support the proposal for system integration. In addition, this review helps fill an existing gap in the literature and guides future experimental studies aimed at simultaneously evaluating trunk control and respiratory function in swimmers.

VII. Conclusion

This narrative review demonstrates that core stability and respiratory efficiency are interdependent components of performance in high-level swimmers. Central stability ensures postural control, hydrodynamic alignment, and effective force transfer between body segments, while efficient respiratory function supports oxygen delivery and ventilatory regulation under conditions of high metabolic demand. The synergy between the deep abdominal muscles, the diaphragm, and the lumbar stabilizers reinforces a functional relationship between posture and breathing, directly contributing to movement economy and endurance.

Accordingly, training programs for elite swimmers should integrate strategies targeting both core strengthening and control, as well as the enhancement of respiratory function, recognizing that balance between these systems may represent a decisive performance factor. Future experimental studies should investigate combined protocols and quantify their effects on physiological, biomechanical, and performance-related variables in order to consolidate evidence applicable to high-performance sports practice.

References

[1]. ARMOUR J, Et Al. The Large Lungs Of Elite Swimmers: An Increased Alveolar Number? Eur Respir J, 1993; 6(2): 237–47.
[2]. CAVAGGIONI L, Et Al. Effects Of Different Core Exercises On Respiratory Parameters And Abdominal Strength. J Phys Ther Sci, 2015; 27(10): 3249–53.
[3]. COHEN RCZ, Et Al. Studying The Effects Of Asymmetry On Freestyle Swimming Using Smoothed Particle Hydrodynamics. Comput Methods Biomech Biomed Engin, 2020; 23(7): 271–84.
[4]. COSTA MJ, Et Al. Relationship Between Front Crawl Trunk Incline And Lower Limbs' Biomechanics In Non-Expert

Swimmers. Applied Sciences, 2025; 15(12): 6676.
[5]. CUNHA M, Et Al. The Effect Of Inspiratory Muscle Training On Swimming Performance, Inspiratory Muscle Strength, Lung Function, And Perceived Breathlessness In Elite Swimmers: A Randomized Controlled Trial. Porto Biomed J, 2019; 4(6): E49.
[6]. DE TROYER A, BORIEK AM. Mechanics Of The Respiratory Muscles. Compr Physiol, 2011; 1(3): 1273–300.
[7]. DELICEOĞLU G, Et Al. Respiratory Muscle Strength As A Predictor Of VO2max And Aerobic Endurance In Competitive Athletes. Applied Sciences, 2024; 14(19): 8976.
[8]. ESER P, Et Al. Improved Exercise Ventilatory Efficiency With Nasal Compared To Oral Breathing In Cardiac Patients. Front Physiol, 2024; 15.
[9]. GUYATT AR, Et Al. Pulmonary Diffusing Capacity In Man During Immersion In Water. J Appl Physiol, 1965; 20(5): 878–81.
[10]. INTERNATIONAL OLYPIC CCOMMITTEE. Rio 2016 Swimming - Olympic Results By Discipline, 2016.
[11]. KARAPOLAT S, DAGLIOĞLU Ö. Effect Of Core Training Program On Respiratory Function And Inspiratory Muscle Strength In Swimmers. European Journal Of Physical Education And Sport Science, 2020; 6(9).
[12]. KARPIŃSKI J, Et Al. The Effects Of A 6-Week Core Exercises On Swimming Performance Of National Level Swimmers. Plos One, 2020; 15(8): E0227394.
[13]. KHIYAMI A, Et Al. Efficacy Of Core Training In Swimming Performance And Neuromuscular Parameters Of Young Swimmers: A Randomised Control Trial. J Clin Med, 2022; 11(11): 3198.
[14]. KWORK WY, Et Al. A Systematic Review And Meta-Analysis: Biomechanical Evaluation Of The Effectiveness Of Strength And Conditioning Training Programs On Front Crawl Swimming Performance. J Sports Sci Med, 2021; 20(4): 564–85.
[15]. KWOK WY, Et Al. The Effect Of The 8-Week Core Muscle Training In Swimming Time, Swimming Force And Core Muscle Activity Among Swimmers: A Randomized Controlled Trial. J Sports Sci Med, 2025; 24(4): 755–63.
[16]. LIEBMAN HL. Estabilidade Do Core: Anatomia Ilustrada: Guia Completo De Exercícios. Barueri: Editora Manole Saúde; 2014.
[17]. LIU S, Et Al. The Effects Of Core Stability Training On Swimming Performance In Youth Swimmers: A Systematic Review And Meta-Analysis. BMC Sports Sci Med Rehabil, 2025a; 17(1): 327.
[18]. LIU S, Et Al. The Effect Of Respiratory Muscle Training On Swimming Performance: A Systematic Review And Meta-Analysis. Front Physiol, 2025b; 16.
[19]. LOMAX M, Et Al. Impact Of Weekly Swimming Training Distance On The Ergogenicity Of Inspiratory Muscle Training In Well-Trained Youth Swimmers. J Strength Cond Res, 2019; 33(8): 2185–93.
[20]. LU ML, Et Al. Development Of Human Posture Simulation Method For Assessing Posture Angles And Spinal Loads. Hum Factors Ergon Manuf, 2015; 25(1): 123–36.
[21]. LUO S, Et Al. Effect Of Core Training On Skill Performance Among Athletes: A Systematic Review. Front Physiol, 2022; 13: 915259.
[22]. MAGEL JR, FAULKNER JA. Maximum Oxygen Uptakes Of College Swimmers. J Appl Physiol, 1967; 22(5): 929–33.
[23]. MAGLISCHO EW. Nadando O Mais Rápido Possível. Barueri: Editora Manole Saúde; 2010.
[24]. MARUYAMA Y, YANAI T. Abdominal Breathing Manoeuvre Reduces Passive Drag Acting On Gliding Swimmers. Sports Biomech, 2015; 14(4): 413–23.
[25]. MCCONNELL A. Respiratory Muscle Training: Theory And Practice. Edinburgh; New York: Churchill Livingstone; 2013.
[26]. MCGILL SM. Enhancing Low-Back Health Through Stabilization Exercise, 2010.
[27]. MURLASITS Z, Et Al. Physiological Responses To An Incremental Swim Test With Different Breathing Frequencies In Competitive Male Youth Swimmers. J Phys Educ Sport, 2023; 23(3): 697–703.
[28]. NASIRZADE A, Et Al. Relationship Between Sprint Performance Of Front Crawl Swimming And Muscle Fascicle Length In Young Swimmers. J Sports Sci Med, 2014; 13(3): 550–6.
[29]. NICOLÒ A, GRUET M, SACHETTI M. Editorial: Breathing In Sport And Exercise: Physiology, Pathophysiology And Applications. Front Physiol, 2023; 14.
[30]. OKADA T, Et Al. Relationship Between Core Stability, Functional Movement, And Performance. J Strength Cond Res, 2011; 25(1): 252–61.
[31]. PÄIVINEN M, Et Al. Swimming-Induced Changes In Pulmonary Function: Special Observations For Clinical Testing. BMC Sports Sci Med Rehabil, 2021; 13(1): 55.
[32]. PEATE I. The Respiratory System. British Journal Of Healthcare Assistants, 2021; 14(4): 174.
[33]. ROCHAT I, Et Al. Determinants Of Lung Function Changes In Athletic Swimmers. A Review. Acta Paediatr, 2022; 111(2): 259–64.
[34]. RODRÍGUEZ S, Et Al. Effects Of Core Stability Training On Swimmers' Specific Performance: A Systematic Review With Meta-Analysis. J Bodyw Mov Ther, 2025; 42: 1063–72.
[35]. SECCHI LLB, Et Al. Dinamometria Isocinética De Tronco Em Nadadores De Diferentes Estilos. Acta Ortop Bras, 2010; 18: 295–7.
[36]. STANDAERT CJ, Et Al. Evidence-Informed Management Of Chronic Low Back Pain With Lumbar Stabilization Exercises. Spine J, 2008; 8(1): 114–20.
[37]. TRINIDAD A, Et Al. Kinematic Determinants Of The Swimming Push Start In Competitive Swimmers. Applied Sciences, 2022; 12(18): 9278.
[38]. VERON HL, Et Al. Implications Of Mouth Breathing On The Pulmonary Function And Respiratory Muscles. Rev CEFAC, 2016; 18: 242–51.
[39]. WEST JB. West's Respiratory Physiology. The Essentials. 10a Ed. Lippincott Williams & Wilkins; 2015.
[40]. WESTON M, Et Al. Isolated Core Training Improves Sprint Performance In National-Level Junior Swimmers. Int J Sports Physiol Perform, 2015; 10(2): 204–10.