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THE ROLE OF PERSONALIZED TRAINING PROGRAMS IN DEVELOPING AEROBIC CAPACITIES AMONG ADOLESCENTS

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Abstract: Adolescence is a critical developmental period where establishing healthy habits, such as regular physical activity, can have a lasting impact on long-term health. However, a global decline in physical activity among teenagers, particularly in aerobic capacity, presents a significant public health challenge. This article examines the role of personalized training programs as a superior alternative to traditional, one-size-fits-all approaches for enhancing aerobic capacity in adolescents. A comprehensive review of recent literature from 2023- 2025 reveals that individualized interventions, which consider factors like biological maturation, baseline fitness, and personal goals, yield significantly greater improvements in key health markers. High-Intensity Interval Training (HIIT) and multi-component programs that combine aerobic, strength, and flexibility training have demonstrated notable efficacy. Studies show that personalized programs can increase VO_2max by 3-5% over short-term interventions, with even greater gains observed when training is tailored to an adolescent's maturity status. Early-maturing adolescents, for instance, show a more pronounced response to training, highlighting the need for a departure from age-based protocols. Furthermore, these programs deliver holistic benefits, including improved muscular strength, favorable body composition changes, and enhanced cognitive function. This article synthesizes the evidence, presents a framework for designing effective personalized programs, and discusses the practical implications for school-based physical education. The findings underscore the necessity of adopting individualized, evidence- based strategies to combat sedentary behavior and foster lifelong physical fitness in the teenage population.

Keywords: personalized training, aerobic capacity, VO_2max, physical education, HIIT, biological maturation, exercise prescription.

1. Introduction

The transition from childhood to adulthood is marked by the critical developmental window of adolescence, a period characterized by profound physical, psychological, and social changes(Mastrorci et al.,2024; Gagné,2019). The habits formed during these years often set the trajectory for long-term health and well-being. Among the most crucial of these is the establishment of a physically active lifestyle(Gagné,2019).

Regular physical activity is a cornerstone of adolescent health, offering a wealth of benefits that extend from improved physical fitness and cardiometabolic health to enhanced mental well-being and academic performance(Ramsey et al.,2021;Bidle et al.,2018) . Despite the well-documented advantages, a pervasive and concerning trend has emerged globally: a significant decline in physical activity levels among teenagers. The World Health Organization (WHO) reports that over 80% of adolescents worldwide do not meet the recommended guideline of at least 60 minutes of moderate-to-vigorous physical activity (MVPA) per day (see WHO,2020;Baquet et al.,2003) . This widespread inactivity is a major contributor to the rising prevalence of noncommunicable diseases (NCDs) such as obesity, type 2 diabetes, and cardiovascular conditions, which are increasingly being diagnosed in younger populations (Weatherwax et al.,2018; Ruiz et al.,2009). Aerobic capacity, or cardiorespiratory fitness (CRF), is a vital component of physical health and a powerful predictor of future health outcomes. Measured by maximal oxygen uptake (VO_2max), it reflects the body's ability to transport and utilize oxygen during sustained physical exertion. Higher levels of CRF in youth are strongly associated with a reduced risk of cardiovascular and metabolic diseases in adulthood(Xu et al.,2025; Schmidt et al.,2016). However, just as overall physical activity has declined, so too has the aerobic fitness of the adolescent population. This decline not only poses immediate health risks but also increases the likelihood of a sedentary lifestyle carrying over into adulthood, perpetuating a cycle of poor health. Traditional school-based physical education (PE) programs, often employing a "*one-size-fits-all*" curriculum, have struggled to effectively address this challenge. Such programs frequently fail to account for the vast diversity in students' fitness levels, biological maturity, interests, and abilities, which can lead to diminished motivation and participation (Lubans et al.,2016). In response to these shortcomings, a paradigm shift towards personalized training programs is gaining momentum. This approach tailors exercise prescriptions to the individual, a strategy that has proven more effective in adult populations and is now showing immense promise for adolescents (Gibala et al.,2012).

This article provides a comprehensive review of the role of personalized training programs in developing aerobic capacity among teenagers. Drawing on the latest evidence from 2023- 2025, it explores the limitations of traditional methods and builds a case for individualization. It delves into the key components of effective personalized programs, including the critical influence of biological maturation, the efficacy of High-Intensity Interval Training (HIIT), and the benefits of a multi-component approach. By synthesizing recent research, presenting data-driven visualizations, and offering a practical framework, this article aims to equip educators, coaches, and health professionals with the knowledge to design and implement more effective, engaging, and scientifically grounded training interventions for the adolescent population.

1.1 **The Importance of Aerobic Capacity in Adolescence**

Aerobic capacity, quantified by VO_2max, is more than just a measure of athletic performance; it is a fundamental marker of overall health, particularly during the formative years of adolescence(Kumari et al.,2024). A robust cardiorespiratory system is integral to an individual's ability to perform sustained physical activity, from participating in sports to engaging in everyday activities with vigor and without undue fatigue. The physiological benefits of high aerobic capacity are extensive and have both immediate and long-term implications(Liang et al.,2025).

1.2 Long-Term Health Predictor

Perhaps the most critical role of adolescent aerobic capacity is its function as a powerful predictor of future health. A substantial body of evidence demonstrates a strong inverse relationship between CRF in youth and the incidence of cardiovascular and metabolic diseases in adulthood. A systematic review and meta-analysis by García-Hermoso et al. (2018) concluded that higher levels of CRF during childhood and adolescence are associated with a healthier cardiometabolic risk profile later in life, including lower blood pressure, more favorable lipid profiles, and reduced insulin resistance .

Furthermore, research has shown that the protective effects of childhood fitness can mitigate the long-term risks associated with other health issues, such as obesity(Logan,2018). A study by Schmidt et al. (2016) found that high levels of childhood fitness significantly reduce the risk of developing metabolic syndrome in adulthood, even for individuals who were obese as children. This underscores the concept that fitness can be a more powerful determinant of long-term health than fatness alone, making the development of aerobic capacity a primary goal for public health interventions.

1.3 Immediate Physical and Mental Health Benefits

Beyond its role as a long-term health marker, adequate aerobic capacity provides numerous immediate benefits that enhance the quality of life for teenagers. Regular engagement in activities that challenge the cardiorespiratory system leads to a host of positive physiological adaptations, including a stronger heart, more efficient circulation, and improved respiratory function(Liang et al.,2025).

These physical improvements are closely linked to mental and cognitive health. Research consistently shows that physically active adolescents with higher CRF report lower rates of depression and anxiety and exhibit higher levels of self-esteem and a more positive body image(Ortega et al.,2007). The neurobiological mechanisms underlying these benefits are multifaceted, involving the release of endorphins, the regulation of neurotransmitters, and the promotion of neurogenesis. High-intensity exercise, in particular, has been shown to increase the concentration of brain-derived neurotrophic factor (BDNF), a protein that plays a crucial role in neuronal survival, growth, and cognitive function (Hillman et al.,2007).

1.4 Academic Performance and Cognitive Function

The connection between physical fitness and brain function extends to academic achievement. Numerous studies have found a positive correlation between aerobic capacity and cognitive performance in adolescents, including improvements in attention, memory, and executive functions(Hillman et al.,2007) . Executive functions, which encompass skills like planning, organizing, and inhibitory control, are critical for success in the classroom and beyond.

A 2025 study by Pérez-Ramírez et al. demonstrated that an 8-week school-based HIIT program led to significant improvements in cognitive outcomes, including a 27.44% increase in concentration and a 53.35% reduction in attention-related errors among participants (Perez-Ramirez et al.,2025) . These findings suggest that interventions aimed at improving aerobic fitness can have a direct and measurable impact on a teenager's ability to learn and succeed academically, making physical education a vital component of a holistic educational strategy.

Given the profound and wide-ranging benefits of aerobic capacity, its decline in the adolescent population is a trend that demands urgent and effective intervention. The subsequent sections will explore why personalized training programs represent the most promising path forward.

2. The Limitations of Traditional "One-Size-Fits-All" Approaches

For decades, physical education in schools has been the primary vehicle for promoting physical activity among youth. However, the conventional model, often characterized by a standardized, "*one-size-fits-all*" curriculum, is proving increasingly inadequate in the face of modern challenges like rising sedentary behavior and declining fitness levels(Papadakis et al.,2021). This approach, while administratively convenient, fundamentally fails to address the diverse needs of the adolescent population, often leading to disengagement, poor skill development, and suboptimal health outcomes.

2.1 Failure to Accommodate Individual Differences

The most significant flaw in the traditional PE model is its inability to accommodate the vast heterogeneity among adolescent students. Teenagers in a single class can vary enormously in their physical capabilities,

baseline fitness levels, body composition, and, critically, their stage of biological maturation. A standardized program that requires all students to perform the same activities at the same intensity inevitably creates a discouraging environment for many. Students at the lower end of the fitness spectrum may find the activities too challenging, leading to feelings of incompetence and frustration. Conversely, highly fit students may find the same activities unchallenging and boring, resulting in a lack of engagement and missed opportunities for further development.

This issue is starkly illustrated in the control groups of recent intervention studies. For example, in the two-year study by Petrovics et al. (2025), adolescent girls in the control group, who participated in traditional PE classes, experienced a significant **4.4% decrease** in their average VO_2max(Faigenbaum et al.,2009). Rather than maintaining or improving their fitness, their aerobic capacity actually declined over the two academic years. This finding is a powerful indictment of the status quo, suggesting that conventional PE may not only be ineffective but could be contributing to the very problem it is meant to solve.

2.2 The Neglect of Biological Maturation

Traditional PE programs are almost universally structured around chronological age, grouping students by their grade level. However, research increasingly shows that biological maturation is a far more influential factor in an adolescent's physical development and response to training than their age in years. During puberty, there is significant inter-individual variability in the timing and tempo of growth, with some adolescents reaching peak height velocity (PHV) years before their same-aged peers.

Treating all 15-year-olds as physically equivalent ignores these profound biological differences. An early-maturing adolescent may possess the strength and coordination of an average 17-year-old, while a late-maturing peer may have the physical characteristics of a 13-year-old(Hananingsih et al.,2024). A one-size-fits-all program fails to provide an appropriate stimulus for either individual. The Domaradzki et al. (2025) study highlights this disparity, showing that early- maturing boys derived significantly greater cardiorespiratory benefits from a HIFT program than their late-maturing counterparts. By failing to account for maturation, traditional programs miss a critical opportunity to optimize training and may inadvertently widen the performance gap between students.

2.3 Lack of Motivation and Long-Term Engagement

Intrinsic motivation is a key driver of lifelong participation in physical activity. When PE is perceived as a mandatory chore characterized by repetitive drills and non-inclusive games, it can extinguish any nascent interest in fitness. The one-size-fits-all model often emphasizes normative comparison—pitting students against each other or against a single performance standard. This competitive structure can be highly demotivating for those who do not perceive themselves as "athletic," fostering a negative affective response to exercise that can last a lifetime(Ahn & Fedewa,2011) .

Personalized approaches, in contrast, emphasize self-referenced goals and individual progress. By focusing on personal improvement rather than comparison to others, students can experience a sense of mastery and competence, which are powerful intrinsic motivators. The study by Petrovics et al. (2025) deliberately communicated this philosophy to its intervention group: "*Our goal is for each of you to improve compared to your own previous performance. We are not comparing you to others, but to yourselves*" (pp.5). This shift in focus is fundamental to changing adolescents' perceptions of physical activity from a requirement to a rewarding and enjoyable pursuit. In summary, the traditional, standardized model of physical education is ill-equipped to develop and sustain aerobic capacity in the modern adolescent population. Its failure to account for individual differences in fitness and maturation, coupled with its often- demotivating structure, necessitates a paradigm shift towards a more scientific and individualized approach.

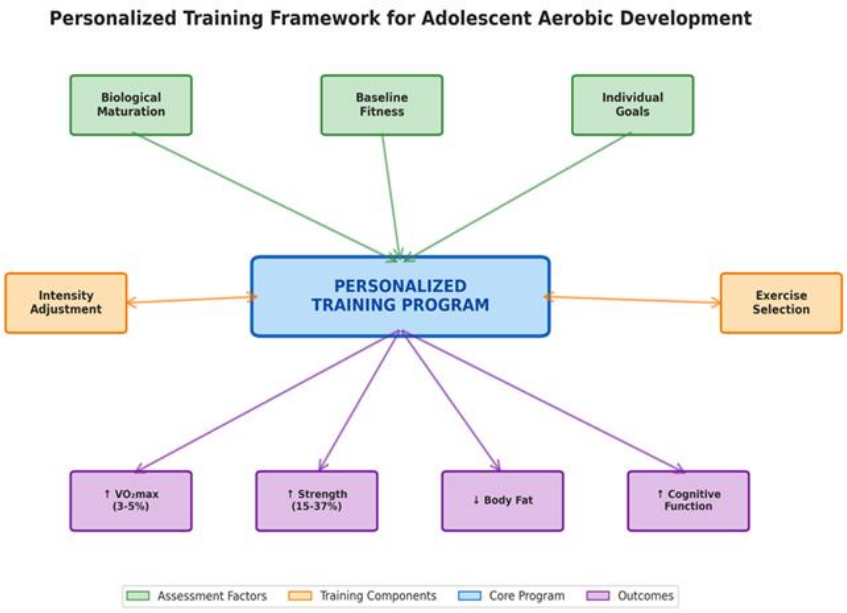
3. The Personalized Training Paradigm: A Superior Approach

In response to the shortcomings of traditional, standardized physical education, the paradigm of personalized training has emerged as a scientifically grounded and demonstrably more effective alternative. This approach moves away from the "*one-size-fits- all*" mentality and instead tailors exercise interventions to the unique characteristics of each individual. By considering a range of factors from biological maturity to personal preferences, personalized programs can optimize physiological adaptations, foster intrinsic motivation, and ultimately achieve superior outcomes in developing aerobic capacity and overall fitness.

3.1 Principles of Personalized Program Design

A successful personalized training program is built upon a foundation of careful assessment and thoughtful planning. The core principles involve understanding where an individual is starting from, where they want to go, and the most effective way to get them there. The personalization frame work represents a conceptual model for designing individualized programs involves three key stages: Assessment, Program Component Adjustment, and Outcome Evaluation. This framework ensures that interventions are both scientifically sound and individually relevant. Figure 1 shows the key components of a personalized training program, from initial assessment factors to the expected health and fitness outcomes.

Figure 1. Personalized Training Framework



1. Comprehensive Baseline Assessment: The starting point for any personalized program is a thorough assessment of the individual's current status. This goes beyond simple observation and involves measuring key health and fitness markers. Essential assessments include:

- **Cardiorespiratory Fitness:** Typically measured via a maximal test or estimated using a validated field test like the 20-meter shuttle run to determine baseline VO_2max.
- **Muscular Strength and Endurance:** Assessed through tests like handgrip strength, push-ups, and curl-ups.
- **Body Composition:** Measuring BMI and body fat percentage to understand health risks and track changes.

- **Biological Maturation:** Estimating maturity offset (years from PHV) to determine developmental stage, which is more informative than chronological age.

2. **Individualized and Self-Referenced Goal Setting:** Unlike normative standards that compare students to each other, personalized programs focus on self-referenced goals. As implemented in the Petrovics et al. (2025) study, participants are encouraged to aim for a realistic percentage of improvement (e.g., 5-10%) from their own baseline measurements (Petrovics et al.,2025). This approach fosters a sense of personal achievement and competence, which are powerful drivers of intrinsic motivation.

3. **Tailoring of Training Variables:** The core of personalization lies in the adjustment of key training variables based on the initial assessment. These variables include:

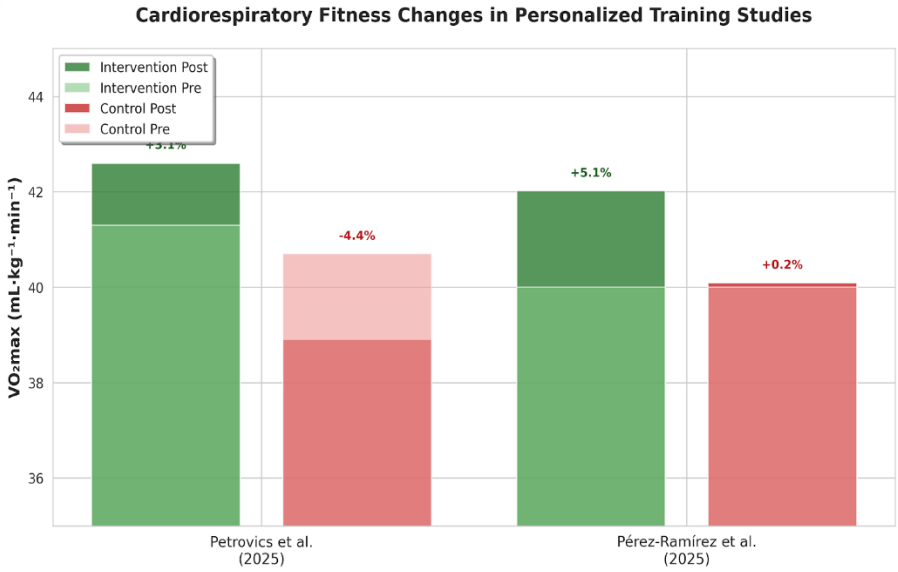
- **Intensity:** Exercise intensity should be prescribed relative to an individual's capacity, such as a percentage of their maximum heart rate (HRmax) or VO_2max, or based on their ventilatory threshold. This ensures the stimulus is sufficient to drive adaptation without being overwhelming.
- **Volume and Duration:** The length of sessions and the total weekly training time can be adjusted based on fitness levels and goals.
- **Exercise Selection:** Incorporating activities that the adolescent finds enjoyable and engaging is crucial for long-term adherence. Providing a degree of autonomy in choosing exercises can significantly boost motivation (Teixeira et al.,2012 ;Standage et al.,2005).

4.2 The Evidence: Superior Outcomes of Individualized Interventions

The theoretical benefits of personalization are strongly supported by empirical evidence from recent studies. When compared directly to traditional PE programs, individualized and structured interventions consistently produce significantly better results in aerobic capacity and other health markers.

The contrast is starkly illustrated when comparing the outcomes of intervention and control groups. As shown in Figure 2, studies implementing personalized or high-intensity protocols report significant gains in VO_2max for the experimental groups, while control groups in traditional PE settings often show stagnation or even a decline in fitness.

Figure 2. Cardiorespiratory Fitness Changes in Personalized Training Studies



*Data sourced from Petrovics et al. (2025) and Pérez-Ramírez et al. (2025)

In the Petrovics et al. (2025) study, the personalized program led to a 3.1% increase in VO_2max and favorable changes in body composition over two years. In stark contrast, the control group's VO_2max decreased by 4.4% over the same period . Similarly, the 8- week HIIT intervention in the Pérez-Ramírez et al. (2025) study resulted in a 5.06% improvement in VO_2max, while the control group saw a negligible 0.22% change .

These findings collectively demonstrate that a structured, individualized approach is not just beneficial—it is essential for reversing the trend of declining adolescent fitness.

5. Effective Methodologies for Personalized Training

While the principles of personalization provide the overarching framework, specific training methodologies have proven particularly effective for developing aerobic capacity in adolescents. The recent literature points to two prominent and highly successful approaches: High-Intensity Interval Training (HIIT) and multi-component programs that integrate various facets of fitness. These methodologies are not mutually exclusive and are often most effective when combined.

5.1 High-Intensity Interval Training (HIIT)

HIIT has emerged as a time-efficient and highly effective strategy for improving cardiorespiratory fitness. This training method involves short, intense bursts of exercise performed at near-maximal effort (typically 85-95% of HRmax), interspersed with brief periods of rest or low-intensity recovery. The appeal of HIIT lies in its ability to produce physiological adaptations comparable or even superior to traditional, longer-duration endurance training, but in a fraction of the time.

5.2 Efficacy and Time-Efficiency

For the school environment, where time is a significant constraint, HIIT is an ideal solution. The study by Pérez-Ramírez et al. (2025) demonstrated that just two 35-40 minute HIIT sessions per week over eight weeks were sufficient to elicit a **5**.06% improvement in VO_2max. The HIFT (High-Intensity Functional Training) protocol used by Domaradzki et al. (2025) was even more time-efficient, with sessions lasting only 6-14 minutes, yet still producing significant fitness gains, particularly in early-maturing adolescents (Domaradzki et al.,2025) .

This efficiency makes HIIT a practical and sustainable option for integration into standard PE classes without requiring a complete overhaul of the curriculum. The ability to achieve significant results with a minimal time commitment is a key advantage in promoting both adoption by schools and adherence by students.

5.3 HIIT Protocols in Practice

The research provides clear examples of effective HIIT protocols that can be adapted for the adolescent population. Table 1 summarizes the key characteristics of training protocols from the studies of Perez-Ramirez et al.,(2025), Domaradzki et al.(2025) and Petrovics et al.(2025), highlighting the variability in session time and structure while maintaining high intensity as a core principle. These protocols often utilize simple, bodyweight-based functional movements such as burpees, squats, lunges, and push-ups, which require minimal equipment and can be easily implemented in a typical school gymnasium. The use of music and a motivating environment, as noted by Pérez-Ramírez et al. (2025), can further enhance engagement and effort during sessions.

Table 1. Comparison of HIIT Protocol Characteristics from Recent Studies

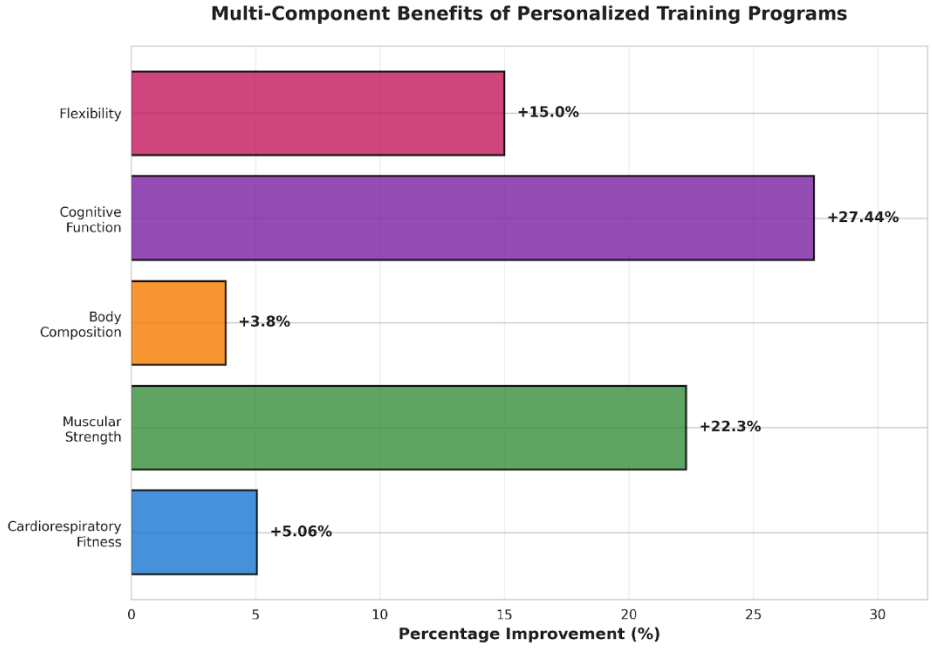
Study	Duration	Frequency	Work: Rest Ratio	Intensity	Session
Pérez-Ramírez et al. (2025)	8 weeks	2x/week	30s : 30s	90-95% HRmax	35-40

Domaradzki et al. (2025)	8 weeks	2x/week	20s : 60s (circuit)	RPE 7-8/10	6-14
Petrovics et al. (2025)	2 years	2x/week	Circuit Training	Individualized	45-60

5.4 Multi-Component Training Programs

While aerobic capacity is a primary goal, a holistic approach to fitness that addresses multiple components—including muscular strength, flexibility, and body composition— yields the most comprehensive health benefits. Personalized programs are uniquely suited to integrate these different elements into a cohesive and effective intervention. The study by Petrovics et al. (2025), which ran for two years, provides a compelling case for this multi-component approach. Their individualized program combined cardiorespiratory training with resistance exercises. The results were impressive and wide-ranging: in addition to the 3.1% increase in VO_2max, participants saw significant improvements in muscular strength (+37.0% in push-ups, +22.3% in curl-ups) and flexibility (+15.0%), alongside reductions in BMI and body fat percentage [13]. Figure 3 presents the visualization of the percentage improvements accross various fitness and health domains from the statistical review of multi-component personalized training program.

Figure 3. The percentage improvements across various fitness and health domains resulting from a multi-component personalized training program



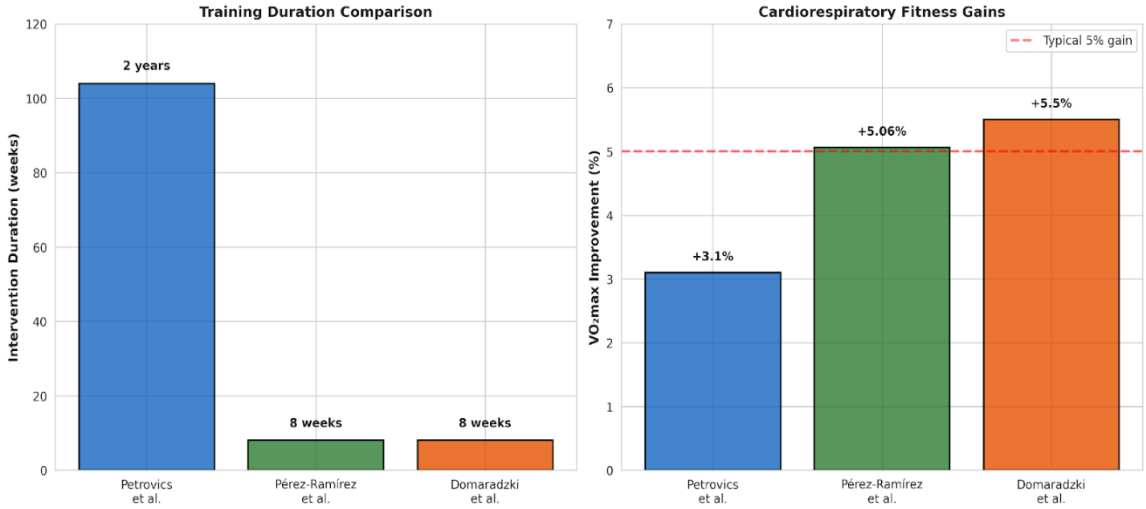
*Data sources from: Petrovics et al. (2025) and Pérez-Ramírez et al. (2025)

The synergistic effect of combining aerobic and resistance training is crucial. Improved muscular strength not only contributes to better performance in daily activities and sports but also has metabolic benefits, such as increased resting metabolic rate and improved glucose regulation. The significant gains in cognitive function observed in the Pérez- Ramírez et al. (2025) study, which used a combined strength and endurance HIIT protocol, further highlight the value of this integrated approach.

Figure 4 provides a comparative look at the training durations and resulting fitness gains from recent studies, illustrating that both short-term HIIT and long-term, multi-component programs can surpass the typical 5% improvement in VO_2max often cited for youth training programs(Baquet et al.,2003). The following figure 4 gives an overview of the results of the interventions durations and the impromevements

in VO_2max from very recent studies. This highlights that well-designed programs can exceed the typical gains expected from standard aerobic training.

Figure 4. A comparison of intervention durations and the corresponding percentage improvements in VO_2max from recent studies.



Ultimately, the most effective personalized programs are those that are dynamic and adaptable, leveraging the time-efficiency of HIIT while incorporating strength and flexibility work to promote whole-body fitness. This holistic approach ensures that adolescents not only improve their aerobic capacity but also build a well-rounded foundation of physical competence that supports long-term health and an active lifestyle.

6. The Critical Role of Biological Maturation

Perhaps the most significant advancement in the field of adolescent exercise science is the growing recognition that biological maturation, not chronological age, is the primary determinant of an individual's response to physical training. The traditional practice of grouping students by their age or grade level for physical education is fundamentally flawed because it ignores the vast and impactful differences in developmental timing that occur during puberty. A personalized approach that accounts for an adolescent's maturity status is essential for optimizing training effectiveness, ensuring safety, and fostering a positive and equitable environment.

6.1 Beyond Chronological Age: Understanding Maturity Offset

Chronological age is a poor proxy for developmental status. Within a single classroom of 15- year-olds, there can be a maturational range of up to five years. Some individuals may be pre-pubertal, while others may be fully mature. These differences have profound implications for physical performance, including strength, coordination, and cardiorespiratory capacity.

To address this, researchers now use the concept of **maturity offset**, which estimates an individual's developmental stage relative to their age at peak height velocity (APHV)—the point of their most rapid growth during the adolescent growth spurt. An individual's maturity offset is expressed in years before or after their APHV. This metric provides a far more accurate and scientifically valid basis for individualizing training programs than chronological age alone.

6.2 Maturation-Dependent Training Responses

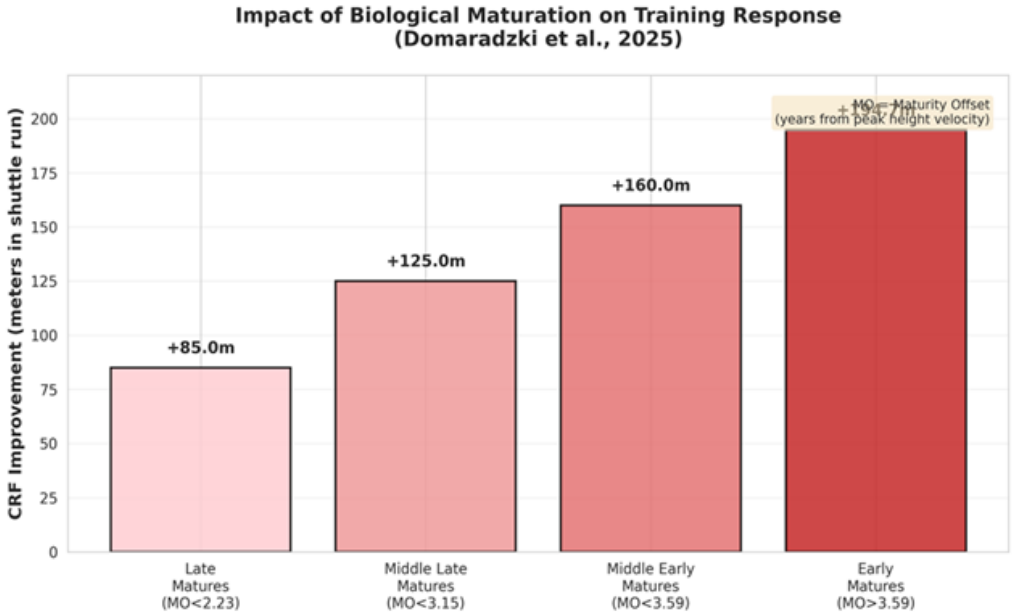
The groundbreaking 2025 study by Domaradzki et al. provides compelling evidence for the critical role of maturation. The researchers implemented an 8-week HIFT program for male adolescents aged 15-18 and

analyzed the results based on the participants' maturity offset. The findings were unequivocal: the training response was significantly dependent on maturational status.

As illustrated in the following Figure 5, the most mature adolescents (those furthest past their APHV) experienced the greatest improvements in cardiorespiratory fitness. The early-maturing group improved their shuttle run performance by an average of 194.7 meters, while the late-maturing group saw substantially smaller gains. Statistical analysis revealed that maturity offset was the main determinant of the change in CRF, explaining **9.3%** of the variance on its own. When combined with chronological age, the two factors explained 15% of the variance, but maturity offset was the far more powerful predictor .

These findings suggest that there are "windows of trainability" during adolescence, where the body is particularly receptive to certain types of training stimuli. Prescribing the same exercise program to an entire age group means that the stimulus will be inappropriate for a large portion of the students—too intense for the late maturers and not challenging enough for the early maturers.

Figure 5. Biological Maturation influence on Training Response



6.3 Implications for Program Design

The evidence supporting maturation-based individualization has clear and actionable implications for the design of adolescent training programs:

1. *Assess Maturation Status*: Whenever feasible, PE programs should incorporate noninvasive methods to estimate maturity offset. The prediction equation used by Domaradzki et al. (2025), which relies on simple anthropometric measurements (height, weight, sitting height), is a practical tool for this purpose .

2. *Group by Maturity, Not Age*: A paradigm shift is needed from age-based groupings to maturity-based groupings. This would allow for the design of programs that are developmentally appropriate for each group, ensuring that the training stimulus is optimized for their current physiological state.

3. *Tailor Intensity and Volume*: For late-maturing adolescents, the focus should be on skill acquisition, coordination, and foundational fitness, with a gradual introduction to higher intensities. For early-maturing adolescents, who are more physiologically robust, the program can incorporate higher-intensity training and greater volume to maximize fitness gains.

By embracing a maturation-based approach, physical educators can move beyond the limitations of the traditional model and create truly personalized and effective training experiences. This shift is not just about improving performance; it is about creating a safer, more inclusive, and more scientifically sound foundation for lifelong physical activity.

7. Conclusion and Future Directions

The evidence presented in this article makes a compelling case for a fundamental shift in how we approach the development of aerobic capacity in adolescents. The traditional, one- size-fits-all model of physical education is no longer sufficient to combat the rising tide of sedentary behavior and the corresponding decline in cardiorespiratory fitness. The future of adolescent fitness lies in **personalization**, a scientifically grounded approach that tailors training interventions to the unique biological and psychological needs of each individual.

Recent research from 2023-2025 has provided robust evidence that personalized programs, particularly those incorporating High-Intensity Interval Training (HIIT) and multi- component methodologies, yield superior outcomes. These programs have been shown to produce significant improvements in VO_2max, muscular strength, body composition, and even cognitive function, often in a remarkably time-efficient manner. Gains in VO_2max ranging from 3-5% over just eight weeks are consistently reported, with long-term, multi- component programs demonstrating sustained benefits and holistic health improvements.

Perhaps the most critical insight from the latest research is the paramount importance of **biological maturation**. The finding that an adolescent's developmental stage is a more powerful predictor of their training response than their chronological age demands a re- evaluation of how we structure physical education. The work of Domaradzki et al. (2025) is a call to action for educators and coaches to move beyond age-based groupings and towards a more nuanced, maturation-aware framework for exercise prescription [53]. By doing so, we can create more effective, safer, and more motivating environments for all students, regardless of their developmental timing.

7.1 Practical Implications and Recommendations

The translation of this research into practice requires a concerted effort from schools, educators, and policymakers. The key recommendations are as follows:

1. *Adopt a Personalization Framework*: Physical education curricula should be redesigned to incorporate the principles of personalized program design, including baseline assessments, individualized goal setting, and the tailoring of training variables.

2. *Integrate Evidence-Based Methodologies*: HIIT and multi-component training should be integrated into PE classes as core methodologies. Their proven efficacy and timeefficiency make them ideal for the school setting.

3. *Prioritize Maturation-Based Grouping*: Schools should explore the feasibility of implementing non-invasive maturation assessments to group students more appropriately, allowing for developmentally tailored instruction.

4. *Focus on Intrinsic Motivation*: The emphasis should shift from normative competition to self-referenced improvement. Fostering a sense of competence, autonomy, and enjoyment is key to building lifelong habits.

7.2 Future Directions

While the evidence is strong, further research is needed to refine and expand our understanding of personalized training for adolescents. Future studies should focus on:

- *Long-Term Longitudinal Studies*: More multi-year studies, like that of Petrovics et al. (2025), are needed to understand the long-term effects of different training modalities on health trajectories into adulthood.
- *Female-Specific Research*: While some studies include female participants, more research is needed to understand the unique responses of adolescent girls to various training protocols, particularly in relation to the menstrual cycle and hormonal fluctuations.
- *Technology Integration*: Investigating the role of wearable technology (heart rate monitors, activity trackers) in facilitating personalized feedback and enhancing motivation in a scalable way.
- *Implementation Science*: Research focused on the practical challenges and facilitatore of implementing personalized, maturation-based PE programs in diverse school settings.

In conclusion, the challenge of improving adolescent aerobic capacity is significant, but the path forward is clear. By embracing the principles of personalization, leveraging effective methodologies like HIIT, and respecting the profound influence of biological maturation, we can empower the next generation to build a foundation of physical fitness that will support their health and well-being for a lifetime.

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Conflict of Interest

The authors declare no conflicts of interest.

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