



Training intensity distribution for sprinter swimmers: suggestions for swimming coaches and scientists

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Received: 8 October 2025 / Accepted: 10 November 2025

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Abstract

The inclusion of the 50 m butterfly, backstroke, and breaststroke events in the 2028 Olympic Games is likely to influence training methodologies and performance trajectories, considering that in competitive swimming, coaches already implement different training approaches for sprinter swimmers. This study examines whether elite sprint specialists, particularly those specializing in 50 m events, should prioritize high-intensity interval training (HIIT) over the traditionally dominant overdistance training models. The discussion aims to inform coaches and researchers about evolving approaches to sprint training and guide future research on intensity distribution in sprint swimming. There is a clear distinction in energy system demands between sprint events: the 50 m event has an aerobic contribution of approximately 20%, while in the 100 m event, the aerobic contribution can rise to around 40–50%. Despite the high anaerobic demands of the 50 m, many coaches continue to implement a Polarized Training Intensity Distribution (TID), characterized by a significant proportion of aerobic training. Based on recent developments in sprint swimming and some aspects of current literature support for the potential benefits of a greater emphasis on HIIT, assisted sprints, and overspeed training, along with earlier and more targeted specialization for sprinters, and an increased emphasis on dryland strength and conditioning. Nevertheless, further studies are needed to examine the efficacy of different TID approaches, particularly for elite athletes specializing exclusively in the 50 m distance.

Keywords Olympic games · High-intensity interval training · Sprint intensity interval training · Repeated sprint training

Introduction

Swimming events are categorized by their race distance, with the shortest official distances—50 and 100 m—considered as sprint events (Ruiz-Navarro et al. 2025). Freestyle

sprinters typically compete in both, following training programs tailored to optimize performance across these distances. In contrast, swimmers specializing in other strokes (butterfly, backstroke, breaststroke) usually train for the 100 and 200 m events (Pelayo et al. 1996; Papadimitriou 2024a), because they have a similar high proportion in the aerobic zone (Rodríguez and Mader 2011). Their training schemes are largely influenced by the competition calendar, with the Olympic Games playing a pivotal role. Historically, only the 50 m freestyle has featured in the Olympic program, prompting swimmers in non-freestyle strokes to focus on longer distances to maximize their qualification and medal chances. Despite 50 m butterfly, backstroke, and breaststroke being already at World Championships, the inclusion of these events in the 2028 Olympic Games offers completely new opportunities for sprint swimmers (McCarvel 2025), producing a crucial change, as without doubt this is the main event in swimming and may result in significant changes in training methods and performance strategies.

Communicated by Michalis G Nikolaidis.

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Specialization is of particular interest in a sport such as swimming, which is characterized by (1) a generally very large distance variety among its athletes and (2) endurance-oriented overdistance training (Pollock et al. 2019). However, top-level 50 m sprinters, defined by World Aquatics points thresholds (≥ 752 for men and ≥ 843 for women), race for approximately 19–25 (men)/22–29 s (women) depending on the swimming stroke (Ruiz-Navarro et al. 2023). These short race durations require athletes to utilize energy generated through the anaerobic pathways predominantly. Anaerobic energy is mainly derived from alactic pathways (efforts lasting 1–12 s) and lactic pathways (efforts ≥ 13 s), involving the breakdown of stored phosphagens [Triphosphoric Adenosine (ATP) and phosphocreatine (PC)] and glycolysis of carbohydrates to pyruvate (Mougios 2006; Affonso et al. 2019; Santos et al. 2022). The aerobic system also

contributes to sprint races (Almeida et al. 2020); however, the anaerobic/aerobic crossover is gradual, not binary, thus contributing to a lesser extent to the high-intensity efforts of sprints due to its slower response time (Gastin 2001). Still essential for the recovery after maximal efforts in training and competition, a well-developed aerobic system is probably an important prerequisite for sprinters, yet not the main limiting factor for world-class sprint times. In this regard, it is important to consider the significant differences in aerobic contribution to 50 (~20%) and 100 m (~40%) events (Toussaint and Hollander 1994). Therefore, we can argue that the 50 m events represent the true sprint category. In comparison, the 100 m events better fit a mid-sprint classification due to their combined aerobic and anaerobic demands.

Generally, swimming is approached as an endurance sport, with swimmers typically conducting high volumes of low-intensity aerobic training (Papadimitriou 2024a) and limited emphasis on HIIT (Papadimitriou 2024b). The emphasis on the development of the aerobic capacity allows for an enhanced recovery and participation in multiple races (e.g., heats and finals) within a single competition day (Zamparo et al. 2011). Moreover, the unique characteristics of the aquatic environment, in which athletes are not exposed to weight-bearing loads and impact forces, allow the usage of higher training volumes (Nugent et al. 2017; Zamparo et al. 2020). Moreover, humans being land-based mammals and not born for in-water locomotion may require a large exposure to the aquatic environment to refine swimming technique and improve movement efficiency/economy (Nugent et al. 2017; Zamparo et al. 2020). However, this traditional approach with a large volume of low-intensity training may not align with the energetic and mechanical demands of sprint swimming, especially for 50 m races (Cuenca-Fernández et al. 2023; Papadimitriou 2024a). The physiological demands and energy contribution of 50 m swimming sprint distance events are summarized in Table 1.

Since sprint events require distinct stroke mechanics and race-pace-specific training to achieve optimal neuromuscular and physiological adaptations (Rodríguez and Mader 2011; Nugent et al. 2019; Ruiz-Navarro et al. 2025), this work examines whether sprint swimming specialists—particularly those targeting the 50 m events (Rodríguez and Mader 2011) should adopt different training programs with a greater focus on methods related to high-intensity training, challenging the conventional overdistance and endurance-oriented training approaches (Pla et al. 2019). The central aim is to show the scarce of literature on sprinters' periodization and what coaches implement for elite sprinters. Simultaneously, we target to provide a critical analysis for coaches and researchers regarding the upcoming inclusion of the 50 m butterfly, backstroke, and breaststroke events

Table 1 Physiological demands and energy contribution of 50 m sprint swimming events

Studies	[La ⁻] (mmol l ⁻¹)	% $\dot{V}O_{2\max}$ (ml/kg/min)	Anaerobic/aerobic contribution (%)	Methodological details
Avloni-tou (1996)	Males AGE1: 9.5±2.2 AGE2: 9.3±1.1 AGE3: 9.0±2.0 Females AGE1: 10.7±2.1 AGE2: 9.3±1.2 AGE3: 9.3±1.9	180	80/20	Different gender and levels
Toubekis and Tokmakidis (2008)				Summarizing data from the literature
Vescovi et al. (2011)	9.1±1.9			100 swimmers (50 males–50 females) 20.2±3.3 y Peak [La ⁻]
Rodríguez and Mader (2011)	—		Phosphagen: 15–80 Glycolytic: 2–80/2–26 Elite swimmers (22 s) 96/4	Summarizing data from the literature
Zacca et al. (2014)	11.03±1.46			12 swimmers 15.6±0.9 years Peak [La ⁻]

[La⁻]: Blood lactate concentration

Table 2 TID according to different training variables

Types of training	Zones	Z1%	Z2%	Z3%
Polarized (Stöggl and Sperlich 2014)	TID _{NS} : Z1 > Z3 > Z2	56–80	0–14	19–33
Threshold (Stöggl and Sperlich 2014)	TID _{NS} : Z1 > Z2 > Z3	39–53	47–61	0
Pyramidal (Filipas et al. 2022)	TID _T : Z1 > Z2 > Z3	75–81	12–18	6–8
High proportion in Z3 (Strepp et al. 2024)	TID _V : Z3 > Z1 > Z2	21–55	0–33	44–
	TID _P : Z1 > Z3 > Z2	42–58	3–25	48
	TID _{HR} : Z1 > Z2 > Z3	35–61	15–37	29–43
				19–31

TID_{NS} training intensity distribution based on the number of sessions, TID_T training intensity distribution based on time spent in each zone, TID_V training intensity distribution based on running velocity, TID_P training intensity distribution based on running power, TID_{HR} training intensity distribution based on heart rate

in the Olympic program a decision that will probably introduce new aspects of training periodization for sprinters.

Training intensity distribution (TID)

Training intensity distribution (TID) describes how training load is allocated across different intensity zones within a macro- or mesocycle. By contrast, High-Intensity Interval Training (HIIT), Sprint Interval Training (SIT), and Repeated Sprint Training (RST) are methods that can be positioned within a TID framework. For example, a polarized TID (Zone 1 > Zone 3 > Zone 2) may include HIIT and SIT sessions in Zone 3, while recovery sets are placed in Zone 1. Thus, HIIT is not a distribution model itself but a training modality applied within one (Stöggl and Sperlich 2014; Wiesinger et al. 2025). This distinction is crucial when evaluating whether specific approaches align with the metabolic and technical requirements of 50 m sprint events.

However, the percentage distribution across these zones varies depending on the sport, the main event's distance, stroke specialization, and performance level (Filipas et al. 2022; Tønnessen et al. 2024). Yet, there is no consensus on the number of zones involved in various TID models. Alternative models propose five, seven, or even eleven zones to capture more granular distinctions in training intensity (Lauren 2021; Sitko et al. 2025). For instance, the British TID model includes five zones: Z1 for aerobic maintenance and development, Z2 for anaerobic threshold, Z3 for $\dot{V}O_{2\max}$ work, Z4 for $[La^-]$ production or tolerance, and Z5 for speed (Fernandes et al. 2024). An additional challenge to the comparability of studies is the various methods to quantify TID. As such, some rely on the number of sessions, others on time spent in each zone, while there is no consensus whether TID is determined by the prescribed time

or actual time spent in each zone; all those approaches can yield marked differences in the training profiles (Stöggl and Sperlich 2014). Based on the most commonly used model for scientific analyses, for the present manuscript, the three-zone model will be adopted (Table 2).

Since 50 m sprint swimmers typically complete their races with less than 30 s, they heavily rely on the anaerobic energy system, particularly the ATP-PCr and glycolytic pathways, and a low aerobic energy contribution (Toubekis and Tokmakidis 2008). As such, endurance-based TID models, including the pyramidal or threshold approach, may not adequately address the metabolic, neuromuscular, and technical demands of swimming sprint events. A high-intensity-focused and modified polarized model featuring a greater proportion of Z3 training, supplemented by low-intensity (Z1) sessions for recovery and technical refinement, may better align with sprint-specific performance requirements. While reverse periodization models emphasizing Z3 remain largely theoretical, they offer promising potential when implemented with close monitoring of recovery and detailed management of fatigue. It may additionally require a solid aerobic capacity, allowing for sufficient recovery abilities, and to transfer the training stimulus into adaptation.

The role of high intensity variations

HIIT plays an important part in endurance sports and affects TID. Depending on the periodization model and time point in the seasons, HIIT accounts for a substantial part of the TID. It has generally been shown that more successful athletes in endurance sports apply a more polarized TID with a larger proportion of HIIT within Z3 (Stöggl and Sperlich 2014). However, especially for swimming, it is important to mention that there are various types of HIIT.

As such, a previous review provided an overview of the various types of HIIT, aiming to specifically target aerobic and anaerobic capacities (Stöggl et al. 2024). It is particularly important to acknowledge that the work-to-rest ratio heavily affects the physiological response to HIIT (Stöggl et al. 2024). More sprint-related protocols improve speed endurance with 10–40 s intervals and a work-to-rest ratio of 1:5/1:8 and (repeated) sprint ability with 2–10 s intervals and a work-to-rest ratio of up to 1:10. By aiming to affect “glycolytic enzymes, lactate dehydrogenase isoenzyme, monocarboxylate transporter, neuromuscular force production, contraction time, neural signaling” as well as movement economy and mechanical efficiency (Stöggl et al. 2024). The sprint-related HIIT protocols are of particular interest to 50 m sprint swimmers, who aim to develop a high anaerobic power and lactate production ability (Price et al. 2024) for a targeted race time below 30 s.

Specifically in sprint swimming, a sprint interval training (SIT) comprised of tethered swimming conducted at 150% of maximal Oxygen consumption ($\dot{V}O_{2\max}$) for 30-s efforts with a 1:1 work-to-rest ratio resulted in a predominantly anaerobic energy contribution during the first two repetitions (anaerobic/aerobic: 74/26% and 53/47%, respectively). However, by the third and fourth intervals, the contribution of the aerobic system shifts in dominance (49/51% and 48/52%). Notably, power output remained consistent throughout the intervals, suggesting that the swimming technique was maintained despite the shift in energy system contribution. Therefore, optimal work-to-rest ratio and recovery intervals play a pivotal role in the optimal application of HIIT. Depending on the intended training adaptation, long rest periods are essential to allow for maximal effort in the enhancement of the speed abilities of pure sprinters. In contrast, aiming to improve lactate tolerance, rest intervals must be shortened to maintain elevated levels of metabolic stress. Excessive recovery in this context may shift the stimulus toward lactate production rather than promoting the physiological adaptations required to tolerate and buffer high levels of acidosis (Phillip and Todd 2003; Bishop and Spencer 2004).

Despite its potential to enhance oxygen transport and utilization (Treff et al. 2019), excessive application of HIIT or SIT involves potential downsides, including the risk of overreaching and diminished physiological adaptations, i.e., impaired mitochondrial function and reduced glucose tolerance (Flockhart et al. 2021). For sprint swimmers, a solid aerobic capacity must be built first to allow for high exercise tolerance in addition to the close monitoring of fatigue and load management. This is also important in the face of the high technical demand of swimming, which requires the maintenance of the quality of the movement throughout the sessions and phases involving a large volume of HIIT. This challenges swim coaches with the difficulty of accurately controlling training intensity zones.

In a recent study, Fernandes et al. (2024) found that swimmers can maintain a stable internal and external load when training at or below the anaerobic threshold, hence during low-to-moderate intensity efforts (Fernandes et al. 2024). However, as intensity increases towards near $\dot{V}O_{2\max}$ intensities with a large proportion of anaerobic metabolism, the physiological stability deteriorates with a remarkable reduction in the quality of the technical execution. This phenomenon occurs in what is commonly referred to as the “grey zone,” where many athletes train without achieving meaningful performance improvements (Ozkaya et al. 2020). Additionally, sprinters engaging in high-lactate production work often experience technical degradation, resulting in movement patterns that differ significantly from their competition form. This raises concerns about transferability.

In disciplines like track, sprinting, or high jump, athletes wouldn’t intentionally train with a technique that deviates from what they use in competition. The risk is that training under conditions that compromise technique could reinforce inefficient or non-specific motor patterns, ultimately limit performance, or even increase injury risk. Maintaining technical integrity, especially in high-speed or skill-dependent events, should remain a priority—even when targeting metabolic adaptations (Haugen et al. 2019). However, on the other hand, in elite female sprinters, progressive lactate accumulation during repeated 50 m bouts was linked with faster times and reduced muscle asymmetry, concluding that lactate may enhance neuromuscular coordination under fatigue (Gołaś et al. 2025).

In summary and in contrast to middle- and long-distance swimming (endurance) events, high-volume–low-intensity training (HVT/LIT) may not be the most effective method to meet the specific energetic and technical demand of sprint swimming. Instead, variations of HIIT may offer additional benefits (Faude et al. 2008; Sperlich et al. 2011; Stöggl et al. 2024).

Overspeed training and assisted sprinting, an additional HIIT approach

Overspeed training and assisted sprinting a HIIT method that is commonly used in swim practice but has been little scientifically evaluated in regard to the optimal training programs, i.e., number of intervals, sprint distance, and length of rest periods. However, assisted sprint swimming may be of particular interest for the development of maximal swimming velocity, particularly in 50 m sprint specialists, who typically struggle to reach their maximal swimming velocities outside of competition. Assisted sprinting may not only help break velocity barriers and reach new individual levels in maximal sprint velocity, but also help with the application of speed endurance (Stöggl et al. 2024) by reducing the metabolic load of each sprint, hence allowing for a larger number of race pace-specific intervals in practice. However, there are only a few studies that have specifically explored the effects of assisted sprint swimming on performance outcomes (Girold et al. 2006). Moreover, little rest (30 s) between the 12 × 25 m sprints and a short training intervention period (3 weeks) limit the practical implications of previous research findings of assisted sprinting on the development of maximal sprint speed (Girold et al. 2006). Additionally, the conventional elastic cords that are typically used for assisted sprinting do not provide continuous assistance and allow swimmers to only swim at their optimal velocity for a short period within each sprint (Girold et al. 2006). Therefore, newer technologies with specific

towing applications provide a well-controlled increase in swimming speed above the individual swimmer's race pace and should be used for training intervention studies.

Beyond elastic cords, several technologies now allow coaches to apply overspeed stimuli more precisely. Motorized towing devices and pulley systems provide continuous, adjustable assistance, enabling swimmers to maintain velocities above race pace for longer distances (Cecilia-Gallego et al. 2022). These systems, however, are typically limited to elite programs with access to specialized equipment. For grassroots or national-level swimmers, elastic cords remain the most accessible method, though they assist inconsistently across the stroke cycle. Therefore, overspeed training must be adapted to the resources available to coaches.

Since there is little research available on assisted sprint swimming, initial study designs can be developed from the literature published on assisted sprint running, although there are biomechanical differences between assisted in-water and on-land sprinting (Cecilia-Gallego et al. 2022). As such, runners have to overcome the higher eccentric forces of assisted vs. normal sprinting. Previous studies encouraged swimmers to focus on maintaining a high stroke rate with the application of assisted sprint swimming, to ensure that they are swimming above their "normal" swimming velocity, rather than being dragged through the water from the additional assistant forces (Girolid et al. 2006). Furthermore, with the application of the right protocol, assisted sprinting may be particularly helpful to transfer strength gains from dry-land interventions to in-water swimming performance. More research is necessary to quantify the most appropriate number of assisted forces and how to assess the quality of the assisted sprints.

What types of training are used by sprinter swimmers?

It is well-established that modern elite sprint programs already integrate HIIT, SIT, dryland power, overspeed, etc., in their periodization. However, one thing is actual practice, and another one is the scientific literature basis. González-Ravé (2021) observed that sprint swimmers commonly follow polarized and threshold TID. There is strong support for allocating a high percentage (70–90%) of training time below the first ventilatory and lactate thresholds, typically at 65–75% of peak oxygen uptake ($\dot{V}O_{2peak}$), under 80% of peak heart rate (HR_{peak}), or with $[La^-]$ below 2 mmol L⁻¹ (Stöggl and Sperlich 2014b). Such low-intensity training has been shown to positively influence sprint performance by mitochondrial biogenesis, lactate exchange, and removal (Esteve-Lanao et al. 2007; Muñoz et al. 2014; Tønnessen et al. 2014; Selles-Perez et al. 2019). The polarized approach

with a larger proportion of HIIT is also known to improve $\dot{V}O_{2peak}$ by increasing stroke and plasma volume, enhancing capillary and mitochondrial biogenesis, and improving the efficiency of key metabolic processes of energy-fueling (Stöggl and Sperlich 2014b).

To allow for a larger proportion of HIIT, the polarized (82/0/18%) TID improved the 100 m performance more compared to a pyramidal TID (60/30/10%) in 12 national-level female swimmers over 12 weeks (Arroyo-Toledo et al. 2021). While both conditions improved $\dot{V}O_{2max}$ and body -Toledo composition (i.e., fat and fat-free mass), the polarized group began with slower baseline times than the pyramidal group. Also, it must be considered the most established of the training principles, which is the variation of the stimulus. Therefore, maybe the whole group was used to performing pyramidal, and consequently, those who followed polarized had greater training variation than the others. At these limits, the evidence provided by this study still provides a starting point for future research (Arroyo-Toledo et al. 2021).

Further evidence that supports the application of a polarized TID has been shown by a study of Pla (Pla et al. 2019). In a 28-week crossover intervention involving 12 males and 10 females (mean age: 17±3 years), participants completed two 6-week periods using either polarized or threshold TID. The polarized model consisted of 81% of training in Zone 1 ($[La^-] \leq 2$ mmol L⁻¹), 4% in Zone 2 ($2 < [La^-] \leq 4$ mmol L⁻¹), and 15% in Zone 3 ($[La^-] > 4$ mmol L⁻¹), while the threshold model followed a 65%/25%/10% distribution. Results showed that polarized training resulted in small to moderate improvements in 100 m performance ($0.97\% \pm 1.02\%$) compared to the threshold approach ($0.09\% \pm 0.94\%$), with less reported fatigue and better recovery quality. Interestingly, the physiological metrics (e.g., $\dot{V}O_{2max}$, $[La^-]$) did not differ significantly between groups, suggesting that performance improvement resulted from altered biomechanical variables. The study conducted a single post-test after only a one-week taper period (Pla et al. 2019). The authors suggest that the results may have revealed greater performance improvements with more pronounced differences between the polarized and threshold TID after a longer taper period. Indeed, for the greatest performance benefits, an up to 21-day taper period involving a 60–90% reduction in training volume and combined with daily high-intensity interval work, has been suggested (Houmard and Johns 1994). Particularly, sprinters may require longer taper phases (3–5 weeks) than middle- and long-distance swimmers (1–3 weeks) (Maglischo 2003), a practical observation that has to be validated with scientific evidence.

A recent case study by Barbosa et al. (2019) examined a world-class sprint swimmer achieving a sub-22-s performance in 50 m freestyle. Over a three-year training phase,

this swimmer followed a polarized TID, with approximately 87–90% of training volume in Zone 1, 0–1% in Zone 2, and 7–12% in Zone 3 (Barbosa et al. 2019). Over the three years, the swimmer showed improvements in stroke length, dry-land strength, and tethered force production. It must be noted, though, that this approach may particularly work for elite swimmers, who already have developed a large aerobic capacity during their junior years. Also, another considerable point is that maybe the TID in terms of time spent in each zone is quite similar between them. Moreover, such a large training volume completed during a time before the three analyzed years of training in the present study may have substantially contributed to the success of the polarized TID with a weekly training volume of as little as 27 km during the preparation and 21 km during the tapering phase. These types of training are particularly important for sprinters and may result in a larger proportion of HIIT in the TID than the previously reported and aforementioned 20%. Therefore, a reevaluation of TID is warranted, tailored specifically to the unique physiological demands of sprint events.

Are we approaching a new training era in sprint swimming? The term of pure sprinter

It is noteworthy that polarized TID originates from endurance sports, where competitions are typically much longer in duration compared to sprint swimming and demand the capacity of maintaining the task-required level of strength as much as possible. While the aerobic-focused training approaches demonstrated benefits on 100 m performance (Pla et al. 2019), the question arises as to what the optimal model for pure sprinters is, i.e., those specialized in 50 m events. Although sprint swimmers have traditionally been treated as endurance athletes, with Polarized, Threshold, and Pyramidal TIDs (Pla et al. 2019; Barbosa et al. 2019), their metabolic profile during competition is more closely related to that of track runners competing in the 200 and 400 m events (similar exercise duration to 50 and 100 m in swimming, respectively) (Spencer and Gastin 2001; Ribeiro et al. 2015). As such, a previous study highlighted that both track and field and swimming events rely on rapid, explosive, and strength movements that demand speed and power (Born et al. 2024b) and raises the necessity for further exploration of the optimal ratios between dry-land and in-water sessions (Issurin 2010; Hellard et al. 2017; Haugen et al. 2019; Strepp et al. 2024).

In track and field, a significant gap exists between scientific research and best practices regarding the application of training principles and methods for elite sprint performance (Haugen et al. 2019). This disparity is particularly evident in the implementation of sprint-specific training components,

where current practices often rely on traditional or block periodization models. Haugen et al. (2019) also highlighted inconsistencies in sprint training design, with considerable variation in distances, intensities, and recovery intervals. In contrast, there was strong alignment between scientific literature and coaching practices in the areas of strength training and tapering.

Back in swimming, sprint swimmers specialized in the 50 m events may prioritize the development of the ability to sustain high levels of anaerobic power and swimming efficiency (Costill et al. 1992; Maglischo 2003), with caution on low-level aerobic training, which can cause neuromuscular fatigue. Therefore, anaerobic key performance indicators, such as maximal $[La^-]$ and VLa_{max} , are of major interest (Sengoku et al. 2024) and are optimally developed through lactate production sets, such as SIT (Terzi et al. 2021), rather than lactate tolerance protocols, such as traditional HIIT or Ultra-Short Race Pace Training (USRPT) (Cuenca-Fernández et al. 2023; Papadimitriou et al. 2023; Papadimitriou 2024a). To select the most promising HIIT protocol, a recent study categorized six variations based on sport-specific demands (Wiesinger et al. 2025). Based on the aspect discussed in the previous paragraph, aerobic HIIT (15–60 s efforts with work-to-rest ratios of 1:1 or 1:0.5), speed endurance maintenance (10–75 s @ 1:1 or 1:3), and speed endurance production (10–40 s @ 1:5 or 1:8) appear to be most suitable for 100 m swimmers.

A recent study by Affonso et al. (2019) enhances the above-mentioned hypothesis. They further underscore the importance of SIT or HIIT sets that target high $[La^-]$ (Affonso et al. 2019). The researchers examined three elite sprint swimmers from the top 10 world ranking and measured their $[La^-]$ levels following maximal 10 and 15 m sprints (lasting approximately 5–7 s). Despite the very short duration of the intervals, $[La^-]$ rose as high as 12–22 mmol L^{-1} . Such elevated $[La^-]$ levels likely reflect the athletes' exceptional muscular strength and power and effective recruitment of fast-twitch type IIb muscle fibers in response to intense external load. These lactate levels were measured 30 s after the exercise bouts, showing the necessity of a high rate of lactate accumulation in addition to the rate of its production (Sengoku et al. 2024; Ruiz-Navarro et al. 2025).

Despite the benefits of SIT and HIIT, the high-intensity TID models heavily depend on the swimmer's training history, background, and performance level. While adult top-elite swimmers may tolerate the excess volume of HIIT (Barbosa et al. 2019), young swimmers may first have to develop the aerobic base to recover from and adapt to the sessions properly. While HIIT should be implemented into a well-designed long-term athlete development system, coaches may face the challenge of managing heterogeneous groups of swimmers and avoiding non-functional

overreaching or even deterioration of physiological functions and performance, particularly in less-trained swimmers (Costill et al. 1992; Maglisco 2003; Flockhart et al. 2021). Furthermore, the general athletic education, particularly on-land strength and power development, should ideally be implemented early in the junior career to lay the foundation for long-term performance potential, especially for those swimmers aiming to become sprint specialists (Born et al. 2023). However, the practical application of the different types of HIIT is limited due to the lack of longitudinal studies in swimming.

Rather than a radical paradigm shift, the emerging evidence suggests a gradual refinement towards sprint-specific training models. For pure sprinters, a higher proportion of Zone 3 training (50–70–80%), supported by targeted Zone 1 recovery (0–50%) and minimal Zone 2 (0–10%), may prove beneficial. This remains a hypothesis requiring longitudinal validation, but it highlights the possibility of evolving from endurance-oriented frameworks to more sprint-focused approaches tailored to the unique energetic and technical demands of the 50 m events.

Limitations of classical models for sprinters

For training to elicit performance improvements, it must involve an appropriate overload and rest. This overload is typically modulated through two primary variables: intensity and volume. By introducing variability, these elements compel the body to adapt. However, beyond simply overloading the system, the stimulus must also be specific to the type of performance desired. Specificity in training ensures that the adaptations align with the competitive demands of the athlete (Issurin 2010). However, this has a direct impact on the quantity and quality of rest provided. Therefore, is this specificity ensured in the long-term preparation of a sprinter?

Traditional periodization models have long emphasized the manipulation of intensity as a key driver of adaptation (Mujika et al. 2019). Most of these models—whether the classical linear models proposed by Matveyev and gathered in Stone et al. (2021), or more complex mixed-intensity progressions—begin with a phase of low intensity that gradually increases throughout the macrocycle. This increase is typically accompanied by a progressive reduction in training volume to trigger adaptations. However, while effective in peaking performance, such models often produce a very short-lived performance peak (Issurin 2010) and are dependent on an extended preparatory period at low intensities, which requires long amounts of rest to produce desired effects. As this cannot always be accomplished, in turn tends to favor aerobic adaptations, which are less relevant and

even counterproductive for sprint swimmers (Haugen et al. 2019). Even alternative models, such as the block periodization approach (e.g., the ATR model: Accumulation, Transformation, and Realization; (Issurin and Kaverin 1985), although more flexible in integrating specific strength and speed work during the Transformation and Realization phases, it still includes a mandatory Accumulation phase, which creates unnecessary fatigue. This phase is typically characterized by high training volumes at lower intensities. While this may benefit endurance-oriented athletes, it can dilute the training specificity required by sprinters, who depend primarily on high-intensity work.

These observations lead us to a critical conclusion: intensity and rest are often the most compromised variables when it comes to programming and periodizing training loads. This presents a significant challenge for sprinters, whose specific performance depends on maintaining high-speed capabilities throughout the year. Sprint swimmers cannot afford extended periods without exposure to high-intensity efforts if they are to remain competitive or qualify for key competitions. Therefore, it becomes essential to explore alternative periodization models that prioritize intensity and sufficient rest from the very first microcycle. These models should aim to maintain a consistently high or at least stable intensity throughout the training cycle, using other variables (such as volume, training frequency, or rest intervals) to create the aimed fluctuations in load. For the sprint swimmer, preserving intensity with appropriate rest is not just a methodological preference—it is a physiological and technical imperative. However, our proposal is hypothetical, and more longitudinal testing is required for safer considerations.

Perspective

Despite the high anaerobic demands of the 50 m, many coaches continue to implement a Polarized TID (Pla et al. 2019), characterized by a significant proportion of aerobic training (Barbosa et al. 2019). Based on recent developments in sprint swimming and current literature, emerging evidence supports the potential benefits of a greater emphasis on HIIT, assisted sprints, and overspeed training, along with earlier and more targeted specialization for sprinters, and an increased emphasis on dryland strength and conditioning (Born et al. 2024a). Further studies are needed to examine the efficacy of different TID approaches, particularly for elite athletes specializing exclusively in the 50 m distance.

Conclusion

Current literature presents a variety of training modalities and sets structures applicable to sprint swimmers. However, grouping the 50 and 100 m events under the same training model appears impractical due to their distinct durations and corresponding energy system demands, especially in high-level sprinters (~22 s). In our hypothesis, the TID for pure sprinters, those specializing in the 50 m, could minimize Z2, while traditional polarized/pyramidal still include 10–20% Z2. Also, we can prioritize Z3 work, followed by a smaller proportion of Z1. In sprint swimming, each 50 m stroke event deserves recognition as a distinct category requiring specialized preparation. Also, the classification of mid-sprinters for 100 m events is supported by current evidence, which shows a significant aerobic contribution at that distance. Elite athletes have demonstrated $[La^-]$ responses exceeding 10 mmol/L even after 10–15 m sprints, underscoring their high anaerobic capacity. If a polarized approach were applied to these athletes, much of the Z2 work might inadvertently fall into the Z3 range, and even low-intensity drills could impose substantial physiological stress, potentially compromising recovery and performance. Of course, future studies are needed, calling for re-evaluation and longitudinal validation of sprint-specific TID models, validating this perspective and guiding evidence-based practice in elite sprint swimming.

Acknowledgements The authors thank and appreciate the valuable and crucial contribution of Dennis Born, who provided key ideas for improving the manuscript.

Author contributions K.P. was involved in conceptualizing the overall study design. All authors were responsible for the interpretation of the writing. All authors were involved in editing drafts of the manuscript. All authors read and approved the final version.

Funding There was no funding.

Availability of data and materials The data are available in the published manuscript.

Code availability Not applicable.

Declarations

Conflict of interest There are no conflicts of interest.

Ethics approval There is no ethical approval issue.

Consent to participate Written informed consent is not necessary for this study.

Consent for publication Not applicable.

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