



International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Operating Publisher
SciFormat Publishing Inc.
ISNI: 0000 0005 1449 8214

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Calgary, Alberta, T3E0A7,
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ARTICLE TITLE

THE EFFICACY OF TRAINING INTENSITY DISTRIBUTION MODELS (POLARIZED, PYRAMIDAL, AND THRESHOLD) IN DEVELOPING AEROBIC CAPACITY IN AMATEUR RUNNERS: A SYSTEMATIC REVIEW

DOI

[https://doi.org/10.31435/ijitss.1\(49\).2026.5237](https://doi.org/10.31435/ijitss.1(49).2026.5237)

RECEIVED

21 January 2026

ACCEPTED

17 March 2026

PUBLISHED

25 March 2026

LICENSE



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THE EFFICACY OF TRAINING INTENSITY DISTRIBUTION MODELS (POLARIZED, PYRAMIDAL, AND THRESHOLD) IN DEVELOPING AEROBIC CAPACITY IN AMATEUR RUNNERS: A SYSTEMATIC REVIEW

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ABSTRACT

Objectives: While the polarized (POL) model is established as the optimal paradigm for elite endurance athletes, its direct application to amateur runners is frequently limited by restricted weekly training volumes (typically 3–5 hours) and perceptual difficulties in self-regulating low-intensity efforts. Therefore, the objective of this systematic literature review is to evaluate the efficacy of Training Intensity Distribution (TID) models - specifically the POL, pyramidal (PYR), and threshold (THR) frameworks - in developing aerobic capacity among this specific population.

Methods: Following the PRISMA framework, a comprehensive search was conducted across PubMed, Web of Science and SPORTDiscus to identify empirical evidence specifically targeting Tier 2 (Trained/Developmental) athletes. To ensure comparability across studies, training loads were synthesized and standardized into a classic triphasic intensity model.

Key Findings: The analysis reveals that amateur athletes exhibit distinct physiological responsiveness compared to their elite counterparts. Due to lower baseline aerobic capacities and greater margins for improvement, PYR and THR models elicit comparable developmental benefits in physiological outcomes, such as maximal oxygen uptake (VO₂max), while demanding significantly less total training time than strict polarization.

Conclusions: Consequently, while strict polarization remains a biological necessity for elite populations managing massive training volumes, PYR and THR distributions present a highly pragmatic, time-efficient, and evidence-based approach for amateur runners aiming to optimize long-term aerobic development.

KEYWORDS

Training Intensity Distribution, Polarized Training, Pyramidal Training, Amateur Runners, Aerobic Capacity, Systematic Review

CITATION

Dawid Szczepański, Anna Gwizdek, Sebastian Konecki, Grzegorz Jałoszyński, Marcin Patryk Barbachowski, Oliwia Marciniak, Maria Kurt, Natalia Bylak, Bruno Makowski, Norbert Gromadzki. (2026) The Efficacy of Training Intensity Distribution Models (Polarized, Pyramidal, and Threshold) in Developing Aerobic Capacity in Amateur Runners: A Systematic Review. *International Journal of Innovative Technologies in Social Science*. 1(49). doi: 10.31435/ijitss.1(49).2026.5237

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Introduction

Endurance running performance is fundamentally underpinned by the systematic manipulation of training intensity, duration, and frequency (Seiler, 2010). Within the domain of high-performance athletics, the Training Intensity Distribution (TID) serves as the structural foundation for physiological adaptation (Foster et al., 2022). Over the past two decades, observational and experimental evidence has consistently identified the Polarized (POL) training model as the prevailing gold standard among elite and world-class endurance athletes (Seiler, 2010). The POL framework is characterized by a high-volume approach where approximately 80% of training sessions are executed at low intensities - typically below the first ventilatory or lactate threshold - while the remaining 20% is dedicated to high-intensity work performed near or above the second threshold (Foster et al., 2022; Seiler, 2010). This dichotomous distribution is theoretically designed to maximize mitochondrial proliferation and peripheral adaptations through extensive low-intensity volume, while reducing the severe autonomic stress and inflammatory responses associated with frequent, monotonic high-intensity loads (Foster et al., 2022).

The widespread documentation of the POL model's efficacy in elite populations has inadvertently catalyzed a "trickle-down effect" in endurance sports, wherein amateur and recreational runners attempt to replicate the regimens of their world-class counterparts. However, this direct translation fails to account for the distinct constraints governing non-elite populations. Utilizing the Participant Classification Framework proposed by McKay et al. (2022), amateur runners training three to five hours per week fall strictly into Tier 2 (Trained/Developmental). Individuals within this tier train regularly with the intent to compete locally, but they lack the immense physiological capacity, time availability, and recovery infrastructure of elites (McKay et al., 2022). Furthermore, Tier 2 athletes frequently lack the physiological awareness required to accurately self-regulate low-intensity efforts, often accumulating excessive fatigue by training harder than intended on

designated easy days (Seiler, 2010). Consequently, attempting to adopt a strict 80/20 POL model within a vastly compressed weekly training volume may yield an insufficient stimulus for optimal aerobic development.

Given these constraints, alternative TID models, notably the Pyramidal (PYR) and Threshold (THR) frameworks, warrant rigorous examination for Tier 2 athletes. While both alternatives share a foundation of low-intensity volume with the POL model, they differ significantly in their distribution of moderate and high-intensity work. The PYR model features a descending volume distribution across low, moderate, and high intensities (approximately 70%-20%-10%), while the THR model allocates a substantial proportion of training to the moderate-intensity domain between the first and second ventilatory thresholds, often referred to as Zone 2 or tempo training (Foster et al., 2022). Therefore, the primary aim of this systematic literature review is to critically evaluate the efficacy of the POL, PYR, and THR training models specifically in developing aerobic capacity among amateur (Tier 2) runners. By synthesizing current empirical evidence, this review seeks to determine whether the elite-centric POL paradigm remains optimal for individuals with limited training availability, or whether the PYR and THR frameworks offer a more pragmatic and physiologically robust solution for this specific population.

Methodology

Search Strategy

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive literature search was performed using PubMed, Web of Science, and SPORTDiscus databases. Search terms included: "Training Intensity Distribution", "Polarized training", "Pyramidal training", "Threshold training", "amateur runners", and "aerobic capacity".

Selection Criteria

Inclusion Criteria:

- Peer-reviewed original research articles involving adult human subjects.
- Study populations strictly classified as Tier 2 (Trained/Developmental) amateur runners, according to the Participant Classification Framework proposed by McKay et al. (2022).
- Studies reporting objective physiological outcomes, such as maximal oxygen uptake (VO_{2max}), or definitive running performance metrics.
- Studies evaluating longitudinal training interventions.

Exclusion Criteria:

- Studies involving elite or world-class athletes (Tiers 4 and 5 of the classification framework).
- Research focusing on non-running sports.
- Studies evaluating solely acute physiological responses without a longitudinal baseline.
- Conference abstracts, non-peer-reviewed publications, and case reports.

Data Extraction and Standardization

Data extracted included participant demographics, specific TID protocols, and physiological outcomes. To ensure comparability across studies, training loads were standardized into the classic triphasic (3-zone) model, following the framework described by Rivera-Köfler et al. (2024): Zone 1 (low-intensity, below VT_1/LT_1), Zone 2 (moderate-intensity, between VT_1/LT_1 and VT_2/LT_2), and Zone 3 (high-intensity, above VT_2/LT_2). The methodological quality and potential risk of bias of the included studies were evaluated using standardized critical appraisal tools.

Results

Physiological Basis of Shaping Aerobic Capacity

Aerobic capacity in endurance athletes is governed by an integrated network of macroscopic (whole-body) and microscopic (skeletal muscle) physiological systems. The interaction of these systems determines an athlete's ability to sustain mechanical work over time by balancing oxygen delivery, oxidative phosphorylation, and the clearance of metabolic byproducts. To understand how specific training distributions - such as the POL or THR models - shape aerobic endurance, it is necessary to establish the underlying physiological determinants that dictate performance.

Macroscopic Determinants of Endurance Performance

Endurance capacity at the whole-body level is classically defined by three interacting parameters: maximal oxygen uptake (VO_{2max}), the lactate threshold, and mechanical efficiency or economy (Joyner & Coyle, 2008). Together, these variables establish the maximum metabolic rate an athlete can sustain and how effectively that energy is translated into speed or power output.

Maximal Oxygen Uptake (VO_{2max})

The upper limit of aerobic metabolism is quantified as VO_{2max} . It represents the integrative capacity of the cardiovascular system to generate high cardiac output, total body hemoglobin to transport oxygen, and the skeletal muscles to extract and utilize that oxygen (Joyner & Coyle, 2008). Specifically, champion endurance athletes typically exhibit relative VO_{2max} values between 70 and 85 ml/kg/min, with female athletes averaging about 10% lower primarily due to differences in body fat and hemoglobin concentrations (Joyner & Coyle, 2008). Furthermore, elite male cross-country skiers and cyclists can reach upper relative limits of ~90 ml/kg/min and absolute values of 7.0–7.5 L/min (van der Zwaard et al., 2021). Among these factors, the dominant physiological adaptation separating trained endurance athletes from untrained individuals is a vastly augmented cardiac stroke volume (Joyner & Coyle, 2008). During intense exercise, VO_{2max} can become a limiting factor; studies indicate that maximal aerobic metabolism can actually decline during a severe 5 to 8 minute bout of exercise due to a fall in stroke volume and reduced oxygen delivery, accelerating muscle fatigue (Joyner & Coyle, 2008).

Metabolic Thresholds and the Aerobic-Anaerobic Transition

Because endurance events are rarely performed at VO_{2max} for their entirety, the fraction of VO_{2max} that an athlete can sustain for a prolonged period - termed "performance VO_2 " - becomes the practical limiter of race pace (Joyner & Coyle, 2008). This sustainable fraction is mapped through the concept of the aerobic-anaerobic transition, a framework consisting of two distinct metabolic breakpoints observed during incremental exercise (Faude et al., 2009).

The Aerobic Threshold (LT_{Aer})

This first breakpoint designates the intensity at which blood lactate concentrations initially rise above resting baseline levels (Faude et al., 2009). Exercise at or slightly above LT_{Aer} relies almost exclusively on aerobic metabolism and can be maintained for hours, with literature indicating that intensities in the range of this first lactate increase can be sustained for approximately 4 hours (Faude et al., 2009). While this intensity represents a shift from absolute baseline, exercise intensities slightly above LT_{Aer} are characterized by blood lactate levels that, although slightly elevated, remain highly stable during steady-state exercise (Faude et al., 2009). It is characterized by elevated but highly stable blood lactate levels and serves as the primary intensity zone for regenerative and high-volume, low-intensity endurance training (Faude et al., 2009).

The Maximal Lactate Steady State ($MLSS / LT_{An}$)

The second breakpoint marks the highest constant workload where lactate production and lactate elimination remain in equilibrium (Faude et al., 2009). Operating at $MLSS$ represents the absolute upper border of constant-load endurance training, a workload that an athlete can typically sustain for 45 to 60 minutes (Faude et al., 2009). Importantly, the constant blood lactate concentration at $MLSS$ is not a universal fixed value; it demonstrates significant individual variability, ranging anywhere from 2 up to 10 mmol/L depending on the athlete and the motor pattern of the exercise (Faude et al., 2009). Any intensity exceeding $MLSS$ shifts the body into a state where mitochondrial oxidation cannot keep pace with pyruvate delivery, leading to an accelerated accumulation of lactic acid, hydrogen ions, and a rapid onset of fatigue (Joyner & Coyle, 2008). Furthermore, exercise above the $MLSS$ triggers an over-proportional release of stress hormones and immunological markers, significantly increasing the physiological toll of the session (Faude et al., 2009).

Mechanical Efficiency and Economy

Efficiency dictates the speed or power generated at a given oxygen consumption rate (Joyner & Coyle, 2008). Oxygen cost for running at a fixed speed can vary by 30-40% among athletes, heavily influencing long-distance performance (Joyner & Coyle, 2008). This variable is strongly linked to microscopic determinants, particularly the proportion of slow-twitch muscle fibers, which exhibit greater mechanical efficiency at the movement frequencies typical of endurance sports (van der Zwaard et al., 2021). Additionally, athletes often employ specific biomechanical strategies to optimize this efficiency. For example, champion cyclists frequently self-select pedal cadences around 90 revolutions per minute, a rhythm that requires relatively low total muscle force per pedal stroke. This specific cadence strategically relies on fatigue-resistant motor units, conserving the more fatigable, high-force muscle fibers for critical race moments (Joyner & Coyle, 2008).

Microscopic Determinants: Skeletal Muscle Adaptations

While whole-body metrics provide a macroscopic view of fitness, the structural and functional characteristics of the skeletal muscle fundamentally dictate the metabolic response to training. Variables such as muscle fiber typology, mitochondrial density, and oxygen supply networks directly govern the location of the aerobic and anaerobic thresholds (van der Zwaard et al., 2021).

Muscle Fiber Typology and the Size Paradox

Endurance athletes generally present a high proportion (70-80%) of Type I (slow-twitch) muscle fibers, which are highly oxidative and mechanically efficient (van der Zwaard et al., 2021). However, the development of these fibers presents a physiological conflict known as the fiber type-fiber size paradox (van der Zwaard et al., 2021).

To produce high force, muscle fibers must increase their cross-sectional area (FCSA). Yet, larger fibers inherently possess longer diffusion distances for oxygen traveling from the capillaries to the mitochondria (van der Zwaard et al., 2021). Consequently, FCSA is negatively correlated with endurance performance and the lactate threshold; athletes with excessively hypertrophied fibers struggle to maintain high oxidative fluxes because oxygen cannot reach the mitochondria fast enough (van der Zwaard et al., 2021).

Mitochondrial Oxidative Capacity

The core of aerobic energy production lies in the mitochondria's ability to resynthesize ATP via oxidative phosphorylation (van der Zwaard et al., 2021). The oxidative capacity of skeletal muscle is highly plastic; targeted endurance training can more than double the tissue's oxidative capacity, largely driving the rightward shift of the lactate threshold seen in trained athletes (Joyner & Coyle, 2008). The activity of enzymes within the Krebs cycle and the electron transport chain (such as succinate dehydrogenase) scales proportionally with body-mass-specific VO_{2max} (van der Zwaard et al., 2021). Fascinatingly, research has demonstrated that VO_{2max} measured during whole-body exercise (such as cycling) utilizes, on average, a staggering 90% of the muscle's maximal mitochondrial oxidative capacity (van der Zwaard et al., 2021). This reveals that at absolute maximal efforts, oxygen supply limitations to the mitochondria are likely marginal. Instead, the mitochondria themselves are operating near their absolute maximum throughput, effectively processing energy at 90% of their absolute capacity (van der Zwaard et al., 2021). By increasing mitochondrial volume and enzymatic activity, the muscle can process a higher rate of pyruvate delivery, thereby delaying the reliance on anaerobic glycolysis and subsequent acidosis (Joyner & Coyle, 2008).

Oxygen Supply: Capillarization and Myoglobin

To resolve the diffusion limitations posed by larger muscle fibers, the body relies on capillarization and myoglobin content (van der Zwaard et al., 2021).

Capillary Density. Endurance training stimulates angiogenesis, drastically increasing the capillary-to-fiber ratio. To visualize this advantage, untrained individuals typically have 3 to 4 capillaries around each muscle fiber, whereas endurance athletes demonstrate 5 to 8 capillaries per fiber - and in elite cases, up to 9 - resulting in exceptionally high capillary densities of 400 to 700 capillaries per mm^2 (van der Zwaard et al., 2021). A dense capillary network not only shortens the oxygen diffusion distance but also facilitates the rapid removal of fatiguing metabolites, such as hydrogen ions (Joyner & Coyle, 2008). Athletes with exceptionally high capillary density can tolerate higher absolute workloads and exercise longer at intensities near VO_{2max} compared to peers with similar lactate thresholds but poorer capillarization (Joyner & Coyle, 2008).

Myoglobin. Operating as the intracellular oxygen transporter, myoglobin concentrations are generally 50% higher in Type I fibers compared to Type II fibers (van der Zwaard et al., 2021). The synergy between dense capillarization and high myoglobin concentration is the primary mechanism that allows elite athletes to accommodate larger muscle fibers without sacrificing mitochondrial oxidative capacity (van der Zwaard et al., 2021).

Training Modalities and Cellular Signaling

The manipulation of training intensity and volume - the core debate between the POL and THR models - results in divergent adaptive signaling pathways within the muscle.

Low-Intensity Training (LIT) Adaptations

High-volume, low-intensity training, which operates below LT_{Aer} , relies on sustained contractile activity over long durations. This sustained duration drives a chronic release of calcium within the muscle, activating signaling cascades that promote mitochondrial biosynthesis (van der Zwaard et al., 2021). Additionally, prolonged low-intensity exercise stimulates muscle protein breakdown via E3 ligases, a mechanism that deliberately keeps muscle fibers small to minimize oxygen diffusion distances, optimizing the muscle for continuous aerobic metabolism (van der Zwaard et al., 2021).

High-Intensity Training (HIT) Adaptations

Conversely, high-intensity intervals performed above MLSS create high metabolic stress, rapidly altering the AMP:ATP ratio and increasing AMPK and PGC-1 α phosphorylation (van der Zwaard et al., 2021). The severe metabolic demand induces local tissue hypoxia, lowering the partial pressure of oxygen and stabilizing transcription factor hypoxia-inducible factor 1- α . This stabilization drastically upregulates the transcription of vascular endothelial growth factor, driving capillary growth, and increases myoglobin

expression (van der Zwaard et al., 2021). Notably, researchers emphasize that this specific adaptive mechanism is particularly effective when high-intensity or sprint interval training is performed under conditions of external (environmental) hypoxia, which supercharges the transcriptional responses for both vascular endothelial growth factor and myoglobin beyond what is achievable in normoxic training (van der Zwaard et al., 2021).

However, applying high-intensity training requires careful periodization. While it powerfully stimulates vascular and myoglobin adaptations, an overabundance of training above the threshold - without adequate low-intensity volume - can actually impair mitochondrial respiratory capacity (van der Zwaard et al., 2021). This physiological reality forms the biological rationale for combining large volumes of low-intensity work with controlled doses of high-intensity work to maximize aerobic capacity. Translating this rationale into daily practice requires a structured framework for quantifying and organizing training loads. In sports science, this framework is defined as the TID, which represents the proportion of total training volume - measured by time or distance - that an athlete spends exercising at low, moderate, or high intensities (Rivera-Köfler et al., 2024).

Defining Training Intensity Distribution and the Three-Zone Model

To accurately categorize TID, researchers and practitioners universally rely on physiological milestones to demarcate training intensities. The gold standard for categorizing these intensities is the triphasic, or three-zone, model. This model partitions exercise intensity based on the body's metabolic responses, specifically using the first and second ventilatory thresholds (VT_1 and VT_2) or the corresponding first and second lactate thresholds (LT_1 and LT_2) (Casado et al., 2022; Rivera-Köfler et al., 2024). Within this triphasic framework, Zone 1 (Z1) represents the moderate exercise domain, encompassing all low-intensity training (LIT) performed below the aerobic threshold (VT_1/LT_1), where blood lactate typically remains stable below 2 mmol/L (Seiler, 2010). Training in Z1 drives peripheral adaptations, including mitochondrial proliferation and increased capillarization of type I muscle fibers (Rivera-Köfler et al., 2024). Zone 2 (Z2) represents the heavy exercise domain, located between the aerobic and anaerobic thresholds, often corresponding to blood lactate levels between 2 and 4 mmol/L. This is frequently referred to as moderate-intensity or threshold training (ThT) (Seiler, 2010). Finally, Zone 3 (Z3) represents the severe exercise domain, where intensity exceeds the anaerobic threshold (VT_2/LT_2) and blood lactate accumulates rapidly. Training in Z3, typically executed as high-intensity interval training (HIT), primarily induces central cardiovascular adaptations, enhances maximal oxygen uptake (VO_{2max}), and recruits type II muscle fibers (Rivera-Köfler et al., 2024).

A common barrier for amateur runners attempting to structure their TID is the misinterpretation of training zones, largely driven by the commercial popularization of a five-zone model. In a five-zone system, zones 1 and 2 generally correspond to "easy" and "moderate" paces. However, physiologically, both zones 1 and 2 in the five-zone model fall strictly within Zone 1 of the scientific three-zone model (Rivera-Köfler et al., 2024). Zone 3 in the five-zone model aligns with Zone 2 in the three-zone model, while zones 4 and 5 represent Zone 3. When recreational runners aim to accumulate time in "Zone 2," they often inadvertently push their intensity into the heavy exercise domain (scientific Z2), misaligning their perceived effort with the targeted physiological stimulus.

This misalignment is further compounded by the methods used to quantify training intensity. Bellinger et al. (2020) demonstrated that the method of quantification - whether utilizing external load (running speed), internal load (heart rate), or perceived load (Rating of Perceived Exertion, RPE) - drastically alters the computation of TID. In highly trained middle-distance runners, utilizing RPE to demarcate training zones resulted in a massive overestimation of time spent in Z2 and Z3 compared to continuous heart rate or running speed monitoring. Specifically, RPE-derived data categorized nearly 60% of training time into Z2 and Z3, whereas heart rate and speed data revealed the athletes were actually spending roughly 80% of their time in Z1 (Bellinger et al., 2020). Bellinger et al. (2020) explain that this drastic misrepresentation occurs because RPE is not merely a function of instantaneous perceived intensity; rather, it is highly susceptible to the accumulating exercise duration, as well as the residual fatigue from previous training sessions and non-training stress. Because amateur runners frequently rely on RPE or subjective feeling rather than precise physiological testing, they routinely underestimate the metabolic cost of their training, leading to unintended variations in their TID.

The Threshold Model

When training intensity is not strictly monitored, amateur runners naturally gravitate toward the THR model. The THR model is characterized by a high proportion of overall training volume conducted in Z2 - often exceeding 20% to 35% of total volume, with some variations pushing the distribution to roughly 45% in Z1, 45% in Z2, and less than 10% in Z3 (Casado et al., 2022; Rivera-Köfler et al., 2024).

Recreationally active individuals and developmental runners frequently self-select this model because Z2 running feels intuitively productive; it is fast enough to elicit a satisfying sense of exertion and fatigue, yet slow enough to be sustained for 30 to 60 minutes. However, relying heavily on the THR model often leads to a stagnant plateau in aerobic capacity. Monotonic loads of high-intensity and THR training induce significant homeostatic disturbances. Continually accumulating time in the heavy exercise domain causes delayed recovery of the autonomic nervous system and elevates inflammatory responses (Foster et al., 2022).

From a mechanistic standpoint, endurance adaptation is driven by cellular signaling, specifically the expression of PGC-1 α , which regulates mitochondrial biogenesis. There are two primary signaling pathways to achieve this: a calcium-dependent pathway stimulated by high-volume, low-intensity training, and an AMPK-dependent pathway activated by high-intensity stress (Foster et al., 2022). The THR model fundamentally compromises both pathways. The intensity in Z2 is not high enough to fully maximize the AMPK signaling pathway - which requires near-maximal Z3 efforts to recruit unrecruited type II motor units and specifically drive increases in capillary density (Foster et al., 2022). Yet the autonomic fatigue generated by Z2 training prevents the athlete from accumulating the massive training volumes required to saturate the calcium signaling pathway in Z1 (Foster et al., 2022). Consequently, amateurs utilizing the THR model find themselves caught in a physiological "no man's land," experiencing high levels of chronic fatigue without the corresponding gains in maximal aerobic capacity.

The Polarized Model (80/20) and Maximizing Adaptive Signals

To circumvent the limitations of THR-heavy training, observational and interventional research over the past two decades has heavily favored the POL model. The POL model completely reorganizes the volume-intensity equation, characterized by accumulating approximately 75% to 80% of total training volume in Z1, with the vast majority of the remaining 15% to 20% conducted in Z3, deliberately minimizing or entirely avoiding Z2 (Casado et al., 2022; Rivera-Köfler et al., 2024). The biological efficacy of the POL model lies in its radical separation of stimuli. By restricting almost all sub-maximal work to Z1, athletes keep autonomic stress and sympathetic nervous system activation relatively low, allowing for rapid recovery and the accumulation of high overall training volumes necessary to drive calcium-mediated peripheral adaptations (Foster et al., 2022; Seiler, 2010). Because the athlete is not carrying residual autonomic fatigue from moderate-intensity Z2 sessions, they approach their Z3 interval sessions fully recovered. This allows them to execute Z3 training at a higher absolute power output, effectively saturating the AMPK signaling pathways and forcing deep central cardiovascular adaptations, including increased stroke volume and enhanced VO_{2max} (Foster et al., 2022).

Intervention studies comparing POL to THR training consistently demonstrate the superiority of polarization. Controlled trials lasting 6 to 12 weeks have shown that athletes randomized to POL training achieve performance improvements that are significantly greater than those following THR-centric programs (Foster et al., 2022). By polarizing the training load, runners maximize the adaptive signals at both extreme ends of the intensity spectrum while mitigating the chronic fatigue associated with the heavy exercise domain.

The Pyramidal Model

While the POL model minimizes Z2 entirely, the PYR model embraces it in a highly controlled manner. The PYR model maintains the massive aerobic base of the POL approach - accumulating roughly 70% to 80% of training volume in Z1 - but structures the remaining intensity in a decreasing step-wise fashion: approximately 15% to 20% in Z2, and a minimal 5% to 10% in Z3 (Casado et al., 2022; Rivera-Köfler et al., 2024).

The application of the PYR versus POL model is heavily dictated by the specific demands of the athlete's target event. Casado et al. (2022) found a distinct trend when comparing elite runners across different distances: 1500m specialists lean heavily toward a POL approach to maximize VO_{2max} and anaerobic capacity in Z3, while world-class marathoners naturally adopt a PYR approach. For a marathoner, Z2 corresponds directly to their specific race pace. Operating at or just below the second lactate threshold (LT_2) improves the muscle's specific capacity to clear lactate while maintaining a high fractional utilization of VO_{2max} over prolonged periods (Casado et al., 2022).

While the PYR model demands more Z2 training than the POL model, it drastically differs from the amateur THR model because the absolute volume of Z1 training remains the dominant foundation. Elite athletes utilizing the PYR model still adhere to a strict "hard day-easy day" paradigm, ensuring that the substantial Z1 volume facilitates recovery from the Z2 tempo runs (Casado et al., 2022; Seiler, 2010).

Comparative Efficacy in Amateur and Recreational Runners

For recreational and amateur runners, the literature presents an intriguing nuance regarding the optimal selection between the POL and PYR models. Both models are overwhelmingly superior to the THR model traditionally adopted by amateurs, primarily because both ensure that approximately 80% of training remains at a truly low intensity (Z1), protecting the athlete from nonfunctional overreaching. However, deciding whether an amateur should polarize (emphasize Z3) or follow a PYR structure (emphasize Z2) depends heavily on their training status.

A comprehensive network meta-analysis of individual participant data by Rosenblat et al. (2025) provides robust statistical evidence that physiological responses to these models are dependent on the athlete's performance level. The authors demonstrated a statistically significant difference in VO_{2max} response: competitive athletes achieve greater improvements in VO_{2max} using the POL model, requiring the highly specific, severe-domain stimulus of Z3 to force further cardiovascular adaptations. Conversely, recreational athletes and amateurs experienced significantly greater improvements in VO_{2max} when utilizing the PYR model (Rosenblat et al., 2025). Because amateur runners possess less training experience and lower baseline aerobic capacities, they have a higher potential to improve through any structured periodization. The PYR model allows amateurs to spend more time practicing biomechanical efficiency and movement economy at tempo paces (Z2), which translates well to amateur racing distances (e.g., 10k, half-marathon) without the severe neuromuscular toll exacted by highly intense Z3 intervals (Rivera-Köfler et al., 2024; Rosenblat et al., 2025).

However, it is crucial to note that while VO_{2max} responses differed between levels, Rosenblat et al. (2025) found no statistically significant differences in actual time-trial (TT) or overall endurance performance between the POL and PYR models, largely due to high individual variability and the heterogeneous nature of TT testing protocols across studies.

Further cementing the "amateur trap" of Z2, Rosenblat et al. (2025) observed a fascinating phenomenon regarding athletes' executed training. When athletes were prescribed strictly low-intensity (LOW) or high-intensity (HIGH) models, their actual completed training - when measured objectively by heart rate - frequently drifted into Z2. Consequently, many athletes inadvertently executed a PYR distribution, perfectly illustrating the natural, magnetic pull of the heavy exercise domain for less experienced runners.

In lower-level athletes, the strict physiological differences between POL and PYR models often become negligible in overall performance outcomes, primarily because any structured shift away from a THR-heavy rut will induce rapid adaptations (Rivera-Köfler et al., 2024). Table 1 synthesizes the typical volume distributions of these three primary models as observed across the literature.

Table 1. Typical Training Intensity Distributions (TID) by Model

| Training Model | Zone 1 (LIT) < LT ₁ | Zone 2 (ThT) LT ₁ - LT ₂ | Zone 3 (HIT) > LT ₂ |
|-----------------|--------------------------------|--|--------------------------------|
| Threshold (THR) | ~45% - 50% | ~35% - 50% | ~5% - 10% |
| Pyramidal (PYR) | ~70% - 80% | ~15% - 20% | ~5% - 10% |
| Polarized (POL) | ~75% - 80% | <5% - 10% | ~15% - 20% |

Note. LIT = Low-Intensity Training; ThT = Threshold Training; HIT = High-Intensity Training; LT = Lactate Threshold. The THR model is commonly self-selected by amateurs but carries a high risk of stagnation due to elevated autonomic stress and limited severe-domain execution (Casado et al., 2022; Rivera-Köfler et al., 2024). The PYR model is dominant among long-distance specialists and is highly effective for recreational runners in maximizing VO_{2max} and building movement economy at race-paces (Casado et al., 2022; Rosenblat et al., 2025). The POL model is considered optimal for competitive/elite athletes as it maximizes dual-pathway adaptations while minimizing central fatigue (Foster et al., 2022; Rosenblat et al., 2025).

Ultimately, whether an amateur runner adopts a POL or PYR approach, the defining characteristic of successful endurance training is the strict preservation of low-intensity volume. By anchoring 80% of training below the aerobic threshold, athletes create the physiological capacity to absorb, execute, and adapt to the higher intensities required to elevate aerobic performance (Casado et al., 2022; Seiler, 2010).

The Amateur Runner As A Specific Research Subject

To accurately evaluate the efficacy of TID, it is necessary to clearly define the population under investigation. In sports science literature, the terminology used to characterize athletic caliber is frequently inconsistent. To resolve this ambiguity, McKay et al. (2022) proposed a standardized six-tiered Participant Classification Framework that categorizes athletes based on training volume and performance metrics. This continuum ranges from Tier 0, representing sedentary individuals, to Tier 5, denoting world-class athletes who secure medals at major global championships. For the purposes of this review, the specific research subject - the amateur runner - is situated strictly within Tier 1, Tier 2, and partially Tier 3, while elite cohorts (Tiers 4 and 5) are explicitly excluded. Within this defined scope, Tier 1 encompasses recreationally active runners who meet the minimum physical activity standards (150 to 300 minutes weekly) but lack a specific focus on structured competition. Moving up the continuum, Tier 2 represents the trained and developmental runner who strongly identifies with the sport, consistently trains roughly three times per week, and maintains a clear intention to compete locally. Finally, Tier 3 captures highly trained runners at a state or national level who execute structured, periodized programs to continually develop their proficiency. By utilizing this framework, the logistical and physiological realities of the amateur runner become distinctly separated from their elite counterparts (McKay et al., 2022).

This classification is not only logistical but also deeply physiological. Recent meta-analytical data demonstrates a stark contrast in aerobic capacity across these tiers; recreational runners (typically Tiers 1 and 2) present an average baseline $\text{VO}_{2\text{max}}$ of approximately $53 \text{ mLkg}^{-1}\text{min}^{-1}$, significantly lower than the $67 \text{ mLkg}^{-1}\text{min}^{-1}$ observed in highly competitive endurance athletes (Rosenblat et al., 2025).

Logistical Constraints and Physiological Profile

The defining logistical constraint of the amateur runner is training volume. As noted by Festa et al. (2020), while professional athletes often accumulate large training volumes distributed across numerous weekly sessions, recreational runners typically average a total weekly training volume of only three to five hours. This restricted capacity is primarily dictated by occupational and lifestyle commitments, heavily limiting the total time available for aerobic development. Because of this lower absolute volume, the risk of non-functional overreaching or overtraining remains remarkably low in amateur populations. Consequently, amateur runners demonstrate a robust physiological tolerance for accumulating a larger proportion of their total training time at moderate intensities without displaying symptoms of overtraining (Festa et al., 2020).

Intensity Drift and Training Quantification Challenges

This tolerance for moderate-intensity work is frequently compounded by the phenomenon of intensity drift. As recently highlighted by Rosenblat et al. (2025), when amateur runners utilize internal physiological metrics, such as heart rate, to monitor their training, they frequently experience an upward drift into higher intensity zones. Specifically, amateur athletes assigned to strictly low-intensity training regimens often accumulate a greater-than-intended volume of their total training time in Zone 2. This inadvertent accumulation effectively shifts their executed training program away from an intended low-intensity focus and into a PYR distribution. This drift occurs primarily because of a well-documented decoupling between internal physiological load and external workload metrics, such as running pace. If a recreational runner is prescribed a steady-state workout near the upper physiological ceiling of Zone 1, their heart rate will naturally drift upward into Zone 2 as the session progresses, even if they strictly adhere to the prescribed external running pace (Rosenblat et al., 2025).

The method used to quantify training intensity fundamentally alters the resulting distribution profile. Although initially demonstrated in highly-trained runners by Bellinger et al. (2020), this phenomenon highlights a universal discrepancy: continuous heart rate monitoring often yields a PYR distribution, whereas external speed metrics from global positioning systems tend to reflect a Polarized distribution. The slower kinetics of the cardiovascular system mean that heart rate takes longer to increase and decrease during fluctuating efforts compared to immediate changes in mechanical running speed, naturally resulting in more time accrued in Zone 2. Furthermore, when athletes utilize the RPE to categorize their sessions, they report significantly greater training time in Zone 2 and Zone 3 compared to what objective heart rate and running speed data indicate. This perceptual overestimation highlights the challenge of maintaining strict intensity discipline within amateur cohorts attempting to execute POL models (Bellinger et al., 2020).

Differential Adaptive Responses to Training Intensity

Consequently, because of these inherent physiological and logistical constraints - coupled with the realities of intensity drift - amateur runners exhibit different adaptive responses to specific TIDs compared to elite competitors. In a comprehensive network meta-analysis, Rosenblat et al. (2025) demonstrated that adaptations in maximal oxygen uptake following different training intensity interventions are highly dependent on the athlete's performance level. The data indicate a statistically significant divergence: while highly competitive athletes tend to experience greater improvements in their aerobic capacity utilizing a POL structure, recreational athletes generally achieve superior developmental benefits from a PYR model.

The underlying mechanism for this divergence relates directly to the training age and accumulated volume of the amateur runner. As explained by Rosenblat et al. (2025), amateur runners possessing fewer lifetime accumulated training hours maintain a much larger margin for initial aerobic improvement. Because they are further from their genetic physiological ceiling, recreational athletes remain highly responsive to a variety of periodization structures, whereas heavily experienced elite athletes require highly specific, polarized stimuli to continue disrupting homeostasis (Rosenblat et al., 2025). Within the limited three to five hour weekly training window available to the amateur, a focused endurance training (FOC) model that emphasizes threshold and moderate-intensity work seems to better meet their physiological needs to maximize training adaptations (Festa et al., 2020). The structured accumulation of moderate-intensity volume provides a potent enough stimulus to drive peripheral adaptations in the amateur runner without triggering the severe autonomic nervous system fatigue that typically plagues elite athletes attempting similar threshold volumes (Seiler, 2010).

Review and Analysis of Intervention Research Results

To accurately interpret the efficacy of various TIDs, it is necessary to contextualize the findings within standardized athlete populations. The Participant Classification Framework provides a robust methodology for categorizing endurance subjects based on training volume, performance metrics, and competitive status (McKay et al., 2022). Within this framework, amateur runners typically fall into Tier 2 (Trained/Developmental), characterized by regular training frequencies of roughly three sessions per week and participation in local-level competitions without achieving national qualifying standards (McKay et al., 2022). In contrast, well-trained and sub-elite athletes represent Tier 3 (Highly Trained/National Level), marked by structured, periodized training designed to reach maximal physiological norms within their given sport (McKay et al., 2022). The physiological margin for improvement drastically narrows as an athlete transitions from Tier 2 to Tier 3, fundamentally altering how the body responds to isolated manipulations of TID.

Direct Comparisons in Recreational and Amateur Cohorts (Tier 2)

In Tier 2 recreational runners, the overarching training impulse - the mathematical integration of exercise volume and intensity - often dictates the magnitude of aerobic adaptation as heavily as the specific distribution of that intensity. To investigate this, Festa et al. (2020) conducted an eight-week intervention involving 38 recreational runners to directly compare the physiological and performance impacts of a polarized endurance training (PET) model against a FOC model. The PET group aimed for an intensity distribution of 77% low intensity (Zone 1), 3% moderate intensity (Zone 2), and 20% high intensity (Zone 3), whereas the FOC group targeted a threshold-heavy distribution of 40% Zone 1, 50% Zone 2, and 10% Zone 3. To isolate the effects of the distribution itself, the researchers strictly matched both groups for total training impulse (TRIMP).

The results demonstrated that both the POL and FOC models elicited significant, yet statistically very similar, physiological improvements across the cohort. Specifically, the PET and FOC groups respectively improved velocity at VO_{2max} by 3.2% and 4.0%, velocity at the ventilatory threshold by 4.0% and 3.2%, velocity at the respiratory compensation threshold by 5.7% and 3.4%, and average velocity during a 2-km running time trial by 3.5% and 3.0%. Neither group exhibited a variation in absolute VO_{2max} parameters. The critical differentiator between the two models was training efficiency. To achieve the matched TRIMP score, the PET group required significantly more time, logging an average of 29.9 ± 3.1 total training hours over the eight-week intervention, compared to only 24.8 ± 2.0 hours for the FOC group. For the amateur athlete burdened by strict temporal constraints, the FOC model provided equivalent physiological adaptations while saving 17% of total training time (Festa et al., 2020)

However, the efficacy of the FOC or THR model over the POL model in amateurs becomes less definitive when examining strict adherence to training prescriptions. To investigate this, Muñoz et al. (2014) examined the impact of TID on 10-km performance in 30 recreational runners over a ten-week period. Participants were randomized into a POL group (aiming for 75% Zone 1, 5% Zone 2, and 20% Zone 3) and a

THR group (aiming for 45% Zone 1, 35% Zone 2, and 20% Zone 3), with total training loads similarly equated using a modified TRIMP approach.

At the conclusion of the ten-week macrocycle, both groups significantly improved their 10-km race times. The POL group improved by an average of 5.0% (119 seconds), while the THR group improved by 3.5% (84 seconds). Due to high standard deviations and individual variations in training response, the 41-second absolute difference in post-training finish times between the groups did not reach statistical significance for the overall cohort.

Yet, many runners struggled to execute the training distributions strictly as prescribed. When the researchers conducted a subset analysis isolating only the 12 highly compliant runners (six from the POL group who successfully achieved a 78/11/11 distribution, and six from the between-THR group who achieved a 32/53/16 distribution), a substantial divergence emerged. The strictly compliant POL subgroup achieved a 7.0% improvement in 10-km performance, compared to just a 1.6% improvement in the compliant THR subgroup. This represented a massive effect size of 1.29 in standardized Cohen units, establishing that when executed with high fidelity, POL training stimulates significantly greater performance enhancement than THR training, even in recreational runners logging low weekly volumes (Muñoz et al., 2014).

The Necessity of Polarization in Well-Trained Populations (Tier 3)

As athletes accumulate training years and transition into Tier 3 classifications, their physiological parameters - such as absolute VO_{2max} and capillary density - approach genetic limits. At this stage, moderate-intensity training loses its potency as a primary driver of aerobic adaptation and may instead contribute excessively to systemic fatigue. To investigate this phenomenon, Esteve-Lanao et al. (2007) conducted a five-month study involving 12 sub-elite endurance runners. The researchers compared a training program emphasizing strict sub-threshold, low-intensity running (Zone 1) against a program emphasizing moderately high-intensity running between the ventilatory and respiratory compensation thresholds (Zone 2). High-intensity interval work (Zone 3) was controlled and equated at approximately 8.5% of the total training time for both groups, and overall training loads were matched via a modified TRIMP approach.

Following the five-month macrocycle, performance in a simulated 10.4 km cross-country race improved in both groups; however, the magnitude of the improvement was significantly greater in the group emphasizing Zone 1 training (an average improvement of 157 ± 13 seconds) compared to the group emphasizing Zone 2 training (121.5 ± 7.1 seconds). The data confirmed that accumulating large volumes of threshold-intensity running (exceeding 20% of total training time) blunts optimal competitive performance. The authors hypothesized that the chronic accumulation of Zone 2 training in athletes already engaging in 5 to 6 hours of weekly volume generates unwarranted sympathetic nervous system stress, potentially resulting in catecholamine depletion or a down-regulation of beta receptors, thereby inhibiting maximal cardiac output during competition (Esteve-Lanao et al., 2007).

Expanding upon this physiological mechanism, Stöggl and Sperlich (2014) conducted a comprehensive nine-week intervention involving 48 highly trained endurance athletes (runners, cyclists, triathletes, and cross-country skiers) possessing baseline peak oxygen uptake values of 62.6 ± 7.1 ml/kg/min. The athletes were randomized into four distinct training models: high-volume training (HVT; achieving an actual distribution of 83/16/1), THR (achieving 46/54/0), high-intensity interval training (HIIT; achieving 43/0/57), and POL (achieving 68/6/26) (Stöggl & Sperlich, 2014).

The results were unequivocal. The POL training model produced the greatest and most comprehensive physiological adaptations across the board, generating an extraordinary 11.7% increase in relative VO_{2max} , a 10.4% increase in absolute VO_{2max} , a 17.4% increase in time to exhaustion during ramp testing, and a 5.1% increase in peak velocity/power output. Both the POL and HIIT models successfully increased velocity/power at a blood lactate concentration of 4 mmol/L by 8.1% and 5.6%, respectively. While the HIIT group did yield a 4.8% increase in VO_{2max} , this adaptation came at a metabolic cost, triggering a 3.7% reduction in body mass indicative of a potential catabolic state or overreaching induced by the chronic high-intensity density. Conversely, exclusive adherence to the THR or high-volume (HVT) training models produced zero significant further improvements in VO_{2max} , time to exhaustion, or peak velocity/power output in this well-trained cohort. These findings solidify the premise that in well-trained athletes, moderate-intensity THR training provides an insufficient stimulus for continued performance enhancement and must be replaced by a highly POL distribution of training stress (Stöggl & Sperlich, 2014).

Dynamic Application: The Periodization of Intensity Distributions

While static analyses of TIDs yield valuable insights regarding their standalone efficacy, elite endurance coaching rarely applies a single distribution model year-round. Instead, athletes periodize these distributions, shifting the mathematical breakdown of time-in-zone as competitive events approach. Filipas et al. (2022) investigated the specific effects of sequencing these models during a 16-week intervention involving 60 well-trained male runners (relative VO_{2max} of 67 ± 4 ml/kg/min).

To evaluate the compounding effects of periodization, the researchers divided the runners into four matched groups differing solely by their temporal distribution patterns: a continuous 16-week PYR model, a continuous 16-week POL, an 8-week PYR model followed immediately by an 8-week POL model (PYR \rightarrow POL), and an 8-week POL model followed immediately by an 8-week PYR model (POL \rightarrow PYR). The PYR distribution consisted of strictly controlled ratios where Zone 1 volume was greater than Zone 2, which in turn was greater than Zone 3 ($Z1 > Z2 > Z3$), whereas the POL distribution ensured Zone 1 was greater than Zone 3, which was greater than Zone 2 ($Z1 > Z3 > Z2$). Crucially, training loads, calculated using TRIMP, were rigidly held constant across all four groups to isolate the manipulation of the intensity distributions independently of training volume variations (Filipas et al., 2022).

Following the 16-week intervention, the sequential shift from a PYR distribution to a POL distribution (PYR \rightarrow POL) proved to be the definitively superior periodization strategy. As documented by Filipas et al. (2022), the PYR \rightarrow POL group exhibited the largest statistically significant improvements in relative VO_{2max} (an increase of approximately 3.0%), velocity at 2 mmol/L blood lactate concentration ($vBLa_2$) (an increase of 1.7%), velocity at 4 mmol/L blood lactate concentration ($vBLa_4$) (an increase of 1.5%), and total 5-km running time trial performance (an improvement of 1.5%).

The success of the PYR \rightarrow POL periodization stems directly from the targeted sequencing of physiological stress. The authors propose that the PYR phase functions effectively during the base or preparatory period, where accumulating moderate-intensity (Zone 2) volume safely develops foundational submaximal running economy and peripheral muscular endurance. Transitioning into the POL phase during the pre-competition block forces an increase in relative intensity - sacrificing the moderate Zone 2 work in favor of highly specific, intense Zone 3 intervals - which is an absolute prerequisite for optimizing the competitive peaking process. Furthermore, through multiple linear regression analysis, the researchers identified that the ultimate 5-km performance enhancements were overwhelmingly driven by improvements in the submaximal variables ($vBLa_2$ and $vBLa_4$) rather than changes in maximal metrics like peak blood lactate or absolute VO_{2max} . This substantiates the concept that while absolute aerobic ceilings may plateau in highly trained runners, the strategic periodization of TIDs - shifting from threshold-inclusive pyramidal loads to threshold-devoid polarized loads - continues to elevate the fractional utilization of VO_{2max} and specific race-pace economy (Filipas et al., 2022).

Discussion

The Optimal Intensity Distribution: A Matter of Athletic Caliber

The determination of an optimal TID is inextricably linked to the athlete's performance caliber and accumulated training history. Recent evidence indicates that adaptive responses to varying TID models differ fundamentally between elite competitors (Tiers 4 and 5) and recreational runners (Tier 2; McKay et al., 2022). As Rosenblat et al. (2025) note, amateur runners respond exceptionally well to a PYR model, effectively developing their aerobic capacity, while the distinct physiological benefits between different TID models often blur in this population. Similarly, Rivera-Köfler et al. (2024) observed that performance differences between TID approaches are largely negligible in lower-level athletes. In contrast, highly competitive and elite professionals strictly require a POL framework to continuously push their physiological boundaries and maximize their peak oxygen uptake (VO_{2max}).

Furthermore, elite runners rarely employ a static TID model year-round. As Casado et al. (2022) demonstrated, high-caliber athletes dynamically manipulate their intensity distribution across the macrocycle. They characteristically construct their aerobic base utilizing a PYR model during the preparatory and precompetitive periods. As they transition into the competitive phase, they systematically decrease their volume in Zone 2, shifting toward a strictly POL model to sharpen their racing form and optimize performance peaks. This observational reality elegantly aligns with the experimental findings of Filipas et al. (2022) discussed previously, which proved the superiority of sequencing from a PYR to a POL model.

The physiological necessity for this strict polarization in elite populations is heavily driven by autonomic constraints. Seiler (2010) explains that athletes accumulating massive training volumes must consciously limit

time spent in Zone 2 (moderate to threshold intensity) to protect the sympathetic nervous system from chronic stress and decompensation. Frequent training at or above the lactate threshold delays parasympathetic recovery and compounds autonomic fatigue over successive daily sessions. Recreational amateurs, conversely, are not bound by this physiological constraint; their severely limited weekly training hours naturally cap their overall systemic stress load. Consequently, amateurs can safely tolerate and benefit from the higher proportion of threshold work characteristic of the PYR model without risking nonfunctional overreaching.

Physiological Mechanisms Underlying Training Adaptations

At the cellular level, the superiority of the POL model can be explained by its ability to concurrently maximize distinct physiological signaling cascades. As Foster et al. (2022) explain, training adaptations rely on two primary cellular pathways that drive mitochondrial proliferation, both of which converge on the expression of the PGC-1 α coactivator. High-volume, low-intensity training - characteristic of Zone 1 in a POL distribution - primarily activates the calcium signaling pathway, which presents a massive adaptive potential. Conversely, high-intensity training (Zone 3) predominantly stimulates the AMPK signaling pathway. While the AMPK pathway quickly saturates, it remains an absolute requirement for comprehensive mitochondrial development. By combining massive volumes of low-intensity work with targeted high-intensity sessions, the POL training model simultaneously maximizes both signaling cascades to optimize mitochondrial synthesis without prematurely exhausting the athlete (Foster et al., 2022).

Furthermore, this POL approach effectively reconciles conflicting physiological adaptations at the microscopic level, addressing what is known as the muscle fiber type-fiber size paradox. As detailed by van der Zwaard et al. (2021), high-intensity intervals act as a potent stimulus for increasing capillary density and myoglobin concentration. Simultaneously, the extensive volume of low-intensity exercise inherent to the POL model induces muscle protein breakdown, actively preventing excessive muscle fiber hypertrophy. Maintaining a smaller muscle fiber cross-sectional area ensures a short, highly efficient diffusion distance for oxygen traveling from the capillaries to the mitochondria, thereby optimizing the muscle's overall oxidative capacity (van der Zwaard et al., 2021).

Ultimately, macroscopic endurance performance is dictated by how effectively these cellular adaptations translate into forward movement. Joyner and Coyle (2008) establish that the remarkable running economy observed in elite athletes is not simply a byproduct of maximal oxygen consumption (VO_{2max}). Instead, performance velocity represents the complex interaction of VO_{2max} , the lactate threshold, and gross mechanical efficiency. Optimal running economy is fundamentally driven by this optimized, cellular-level muscular efficiency, which allows the athlete to translate aerobic energy production into sustained power and speed without crossing the threshold of metabolic failure (Joyner & Coyle, 2008).

Practical Implications and Execution Challenges

The accurate execution of a POL training model relies heavily on the strict demarcation of intensity zones, a task that proves challenging when amateur runners (Tier 2; McKay et al., 2022) depend on subjective measures. Bellinger et al. (2020) demonstrated that the method of training intensity quantification substantially affects the resultant distribution. When utilizing the RPE, even highly trained runners consistently misjudge their effort, heavily overestimating the time actually spent in Zone 2 and Zone 3 compared to objective heart rate and running speed calculations. This perceptual error often stems from prolonged exercise duration, residual fatigue from previous sessions, and non-training stressors artificially elevating perceived effort. Consequently, an amateur runner might rate a recovery run as a moderate or high-intensity session despite their heart rate remaining strictly in Zone 1. This inability to accurately gauge low intensity disrupts the rigorous boundaries of the POL model, causing amateurs to naturally drift into the proverbial "black hole" of moderate-intensity training.

Beyond perceptual errors, absolute time constraints represent the primary limiter for recreational runners aiming to adopt elite-level distributions. While the POL model is heavily favored for elite athletes (Tiers 4 and 5) managing massive training volumes to prevent overtraining, amateur runners typically average only three to five hours of training per week. Festa et al. (2020) established that a FOC - which essentially functions as a THR distribution by allocating roughly 50% of training volume to Zone 2 - yields comparable conditional and performance improvements to a POL approach in recreational populations. Notably, the FOC model achieved these identical physiological gains while being significantly more time-efficient, requiring 17% less total training time over an eight-week intervention.

Therefore, the PYR or THR frameworks serve as a highly pragmatic and often necessary compromise for amateurs. While elite populations must utilize strict polarization to maximize their absolute physiological limits safely, recreational athletes benefit from an approach that prioritizes time-efficiency and balances

adaptation with reality. These moderate-volume, threshold-inclusive models protect them from the unrealistic volume demands of the POL regimen while naturally accommodating their lifestyle time limits and inherent errors in intensity perception.

Limitations of Current Evidence and Future Directions

As recently highlighted in the comprehensive network meta-analysis by Rosenblat et al. (2025), a primary limitation in contemporary endurance training literature is the pervasive reliance on inadequately powered, small-sample studies. This constraint severely hinders the statistical power required to detect true performance differences between TID models, thereby elevating the risk that observed intervention effects- or the lack thereof - are merely the result of sampling error. Furthermore, cross-study comparisons are complicated by a profound lack of methodological consistency in defining training zones. Researchers frequently employ disparate physiological markers to demarcate the borders between intensity domains, such as alternating between the first ventilatory (VT_1) or lactate (LT_1) thresholds for the lower boundary, and the second ventilatory (VT_2) or lactate (LT_2) thresholds for the upper boundary. Combining datasets that rely on these differing methodologies to program exercise intensity introduces substantial inaccuracy.

To advance the field, future research must prioritize standardized testing protocols and larger cohorts to establish robust statistical power. Moreover, subsequent study designs should pivot toward a more holistic quantification of TID by integrating internal physiological metrics, such as continuous heart rate monitoring, with external workload metrics like running pace or mechanical power output. Capturing both internal and external training loads will yield more precise data regarding exercise intensity and improve the accuracy of predicting performance outcomes across varied endurance populations (Rosenblat et al., 2025). Despite these methodological limitations within the current literature, POL, PYR and THR models remain the most robust and evidence-based frameworks upon which modern endurance training is founded.

Conclusions

The determination of an optimal TID is inextricably linked to an athlete's performance caliber, training history, and available volume. While highly competitive and elite runners within Tiers 4 and 5 strictly require a POL framework to continuously disrupt homeostasis and push their physiological boundaries safely, recreational and amateur runners in Tier 2 exhibit distinct adaptive responses. For these developmental athletes, possessing fewer lifetime accumulated training hours and lower baseline aerobic capacities, the strict physiological superiority of the POL model becomes less definitive. Research demonstrates that PYR and THR models elicit significant and comparable physiological improvements in amateur cohorts, effectively developing maximal oxygen uptake and running economy. Because amateurs maintain a larger margin for initial aerobic improvement, the overarching training impulse often dictates the magnitude of adaptation as heavily as the specific mathematical distribution of intensity.

Beyond physiological responsiveness, the execution of elite-level TID models by recreational runners is frequently compromised by substantial logistical and perceptual barriers. A primary limitation is the strict temporal constraint dictated by occupational and lifestyle commitments, typically restricting amateur training volumes to merely three to five hours per week. Furthermore, accurately executing a POL model requires a rigorous demarcation of intensity zones, which proves highly challenging for athletes relying on subjective measures. When utilizing the RPE, even trained runners consistently overestimate their effort and misjudge low-intensity recovery runs, leading to an inadvertent upward intensity drift. This inability to accurately gauge low intensity disrupts the rigorous boundaries of the POL regimen, causing amateurs to naturally gravitate toward the heavy exercise domain of Zone 2.

Consequently, while strict polarization remains a biological necessity for elite populations managing massive training volumes to protect the sympathetic nervous system from chronic decompensation, such a framework is neither practically mandated nor logistically feasible for most Tier 2 athletes. Instead, the PYR and THR frameworks serve as a highly pragmatic and necessary compromise. These moderate-volume, threshold-inclusive models accommodate the inherent errors in amateur intensity perception and naturally align with lifestyle time limits. Notably, threshold-based training provides equivalent physiological adaptations to POL training in recreational cohorts while requiring significantly less total training time, highlighting its superior time-efficiency. Therefore, for the amateur runner, adopting a PYR or THR distribution balances physiological adaptation with practical reality, providing an effective, evidence-based stimulus for long-term aerobic development.

Ethical Considerations Plagiarism: The manuscript represents original work and has not been published elsewhere.

Ethics Approval: As this study is a systematic literature review synthesizing previously published research, ethical approval from an institutional review board was not required.

Conflicts of Interest: The authors declare no conflicts of interest.

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