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Human Kinetics
BRIEF REVIEW

Training Periodization, Intensity Distribution, and Volume in Trained Cyclists: A Systematic Review

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A well-planned periodized approach endeavors to allow road cyclists to achieve peak performance when their most important competitions are held. ***Purpose:*** To identify the main characteristics of periodization models and physiological parameters of trained road cyclists as described by discernable training intensity distribution (TID), volume, and periodization models. ***Methods:*** The electronic databases Scopus, PubMed, and Web of Science were searched using a comprehensive list of relevant terms. Studies that investigated the effect of the periodization of training in cyclists and described training load (volume, TID) and periodization details were included in the systematic review. ***Results:*** Seven studies met the inclusion criteria. Block periodization (characterized by employment of highly concentrated training workload phases) ranged between 1- and 8-week blocks of high-, medium-, or low-intensity training. Training volume ranged from 8.75 to 11.68 $h \cdot wk^{-1}$ and both pyramidal and polarized TID were used. Traditional periodization (characterized by a first period of high-volume/low-intensity training, before reducing volume and increasing the proportion of high-intensity training) was characterized by a cyclic progressive increase in training load, the training volume ranged from 7.5 to 10.76 $h \cdot wk^{-1}$, and pyramidal TID was used. Block periodization improved maximum oxygen uptake (VO_2max), peak aerobic power, lactate, and ventilatory thresholds, while traditional periodization improved VO_2max, peak aerobic power, and lactate thresholds. In addition, a day-by-day programming approach improved VO_2max and ventilatory thresholds. ***Conclusions:*** No evidence is currently available favoring a specific periodization model during 8 to 12 weeks in trained road cyclists. However, few studies have examined seasonal impact of different periodization models in a systematic way.

Keywords: cycling, competition, elite athletes

Road cycling is characterized by races of 1- to 6-hour duration, and the biggest events consist of multistage races with back-to-back days of racing over long distances punctuated with shorter, intense individual time trials (TTs).[1] The Grand Tours (Vuelta a España, Giro d'Italia, and Tour de France) are contested over a 3-week period. Therefore, a World Tour cyclist may have 60 to 80 competition days in a season, contested in races of 1 day, 2 to 3 days, and 1 to 3 weeks. Competitive road races are characterized by their diverse topography. For example, different stage types have been described: flat terrain (5- to 30-s efforts), semimountainous terrain (30-s to 2-min efforts in multiday stages and 30-s to 10-min efforts in typical decisive segments), mountain terrain (>10-min efforts), and TTs (>10-min efforts).[2] A Men's World Tour team may comprise 30 riders and at any given time in the season, these riders may be racing as smaller units of 5 to 8 riders in 3 different international events, while others recover from illness, injury, or train at home. Therefore, cyclists and coaches plan and adjust their training based on team needs considering all the variables in relation to the cyclist's competitive context.

It has already been 20 years since descriptive studies emerged quantifying the training of professional road cyclists.[3,4] With digital monitoring technologies, access to daily training data from elite road cyclists has greatly expanded in recent years.[5–9] These developments have also energized discussions about training periodization in cycling.

Recent studies on periodization in individual sports have described both a traditional (TP) and a block (BP) model of training periodization, each offering a differing rationale and template for the subdivision of the annual program into sequential elements.[10] Arguably, the original concept of periodization was proposed initially by Boris Kotov in his book "Olympic Sport" in 1916.[11] Later, Issurin[12] affirmed that Pihkala[13] postulated a number of principles such as dividing the annual cycle into preparatory, spring, and summer phases, and including a period of active rest after completing the season.

The TP was developed by Matveyev[14] for improving the sporting performance of elite Soviet athletes. Each annual cycle was divided into preparatory, competitive, and transition periods following the Matveyev model, with the aim of building aerobic capacity first through a period of high-volume/low-intensity training (LIT), before reducing volume and increasing the proportion of high-intensity training (HIT). The TP has been the most frequent model reported in individual sports such as swimming,[15,16] and track and field, and road distance events.[17–19] However, in road cycling, periodization has not been studied extensively enough to make informed, generalizable conclusions about the physiological impact of different phases in the model.

The TP model has been challenged in recent years for lacking an evidence base.[20,21] This knowledge gap seems to be due, at least in part, to the logistical challenges associated with comparing different forms of training within athlete groups. Furthermore, the long seasons and extreme competition schedules of modern endurance athletes challenge the assumptions underlying

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traditional periodization (TP).[22] Kiely also highlighted weak points in TP as frequent performance peaks within the same competition year, and a deep and specialized focus on the effects of training in a relatively short time. The BP training approach is presented as an efficient/efficacious alternative to TP. The primary premise of BP is the employment of highly concentrated training workload phases (periodization blocks) and the resulting after/residual effects. In opposition to the periodization paradigms described by Matveyev and Issurin, Kiely[20,21] has questioned periodization's conceptual foundations, and he defends a new paradigm to reevaluate the "conventional doctrine" and to evolve more nuanced and perceptive training planning perspectives. Kiely et al[23] criticized the BP model, arguing the lack of scientific foundation proposed by Issurin,[24] based on "biological misconceptions" entrenched within the proposed "accumulation, transformation, and realization" mesocycle terminology used. Currently, there is a lack of studies offering a framework for specific characteristics of a cycling-specific periodization (traditional vs block), including volume and training intensity distribution (TID) across the span of a season. Moreover, "periodization" and "programming" are terms that are often confused and used interchangeably because different authors do not distinguish periodization (long-term global organization and sequencing of training) from programming (short-term prescription of training sessions and sets), as reported by Kataoka et al[25] and Hammert et al.[26]

Traditionally, 3 physiologically distinguishable training intensity zones are detailed in the literature for endurance athletes.[27,28] These zones (z1, z2, and z3) can be individually determined by the first and second ventilatory thresholds or blood lactate turn points.[29] Pyramidal and polarized TID models are both characterized by 80% of volume in z1. However, the remaining 20% in the pyramidal TID model is conducted in z2 and z3, while in the polarized TID model this 20% is conducted at primarily in z3, and as little training as possible in z2. In contrast, the threshold TID model features a high proportion of volume conducted in z2 (ie, >35%) and the remaining in z1.[19,29] TID models with both 4 and 5 zones have also been reported for cycling studies.[30,31] When an athlete is training for an endurance event, the commonly used periodization model is TP , which usually involves different TID approaches across sequential periods.[32,33] For example, World Tour cyclists are characterized by an annual volume of ~680 to 730 hours, distributed mostly in Z1 (~470–500 h, 67%–69%) and less in Z2 (~24–40 h, 4%–5%), Z3 (~22–32 h, 3%–4%), Z4 (~8–16 h, 1%–2%) and Z5 (~2–7 h, 0.3%–1%), competition (~60–92 h, 9%–12%), and other training (~70–78 h, 10%).[5] Given the large contribution of competitions to total training load in elite road cyclists, the periodization of training in these athletes is particularly challenging based on the competition calendar, needs of team, and different stage types during the season.

The aims of this systematic review were, therefore, 2-fold, as follows: (1) to describe the characterization of BP and TP models on endurance performance and physiological parameters in trained cyclists and (2) to describe the volume and TID of each periodization model of studies evaluated.

Methods

Literature Search

This systematic review followed the guidelines established by the PRISMA statement.[34] A literature search was conducted on October 25, 2021, by 2 independent reviewers for the following databases: PubMed, Web of Science, and Scopus. The keywords used in the search were as follows: "periodization," or "training periodization," or "block periodization," and "traditional periodization" AND "cycling" OR "bicycling" OR "cyclist." Searches were limited to human participants and English language-only publications. Two reviewers (Galán-Rioja and Gonzalez-Ravé) independently performed the identification, screening, eligibility, and inclusion of studies, with disagreement settled by consensus. All records from the literature search were examined by title and abstract to exclude irrelevant records. Studies were selected following the eligibility criteria. Additional records were identified through other sources (such as manual searches through article reference lists). The data included the publications details, participants characteristics, training intervention, type of periodization, TID analysis, duration, and performance determinants results were extracted from all eligible studies.

Inclusion and Exclusion Criteria

Studies were included in the present study based on the following criteria: (1) published in English, (2) in a peer-reviewed journal, (3) included youth or adult competitive cyclists, (4) provided documentation of the endurance training programs related to the goal of improving parameters determinants performance in cycling, (5) evaluated BP and/or TP models, and (6) quantified the TID and volume of training.

The exclusion criteria were as follows: (1) athletes from other sports not associated with performance cycling, (2) studies of less than 8 weeks and/or not detailing the training program intervention, and (3) outcome variables unrelated to performance determinants.

Data Extraction

A total of 1472 studies were identified (Figure 1). Overall, 12 studies were identified initially that were full-test screened (Figure 1), however, only 7 of these 12 studies were included in the systematic review, based on the inclusion criteria. Five studies were excluded for different reasons after final reading.[27,28,30,31,35–37] From these 7 studies, 161 participants, male and female, aged 18–41 years (age = 32.5 [7.5] y, height = 1.8 [0.0] m, weight = 72.6 [4.7] kg, maximum oxygen uptake [VO_2max] = 60.8 [5.9] $mL \cdot kg^{-1} \cdot min^{-1}$) were included in the characteristics of the studies (Table 1). We extracted the following data from each eligible trial: authors; year of publication; number of participants, sex, training intervention; type of periodization which includes TID and volume; and physiological/performance factors such as $\dot{V}O_2$max (in milliliters per kiloram per minute), gross efficiency (GE), power output at different thresholds (lactate threshold, first and second ventilatory thresholds), as well as other determinants and results of study.

Quality Evaluation

The quality of the studies included in the review was evaluated by 2 observers (Galán-Rioja and Gonzalez-Ravé). All the studies were carefully analyzed with the PEDro scale[38] (Table 2). Item 1 is rated for external validity (yes/no) and items 2 to 11 for internal validity (rated using 0 as absent or 1 as present). Given that the assessors are rarely blinded, and that it is impossible to blind the participants and investigators in supervised exercise interventions, the items related to blinding were removed[6–8] from the scale.[39] For this reason, the highest score was 6 points, as the first item is not included in the total score, similar to previous systematic reviews[38] as follows: 6 to 7 = "excellent," 5 = "good, " 4 = "moderate," and 0 to 3 = "poor."

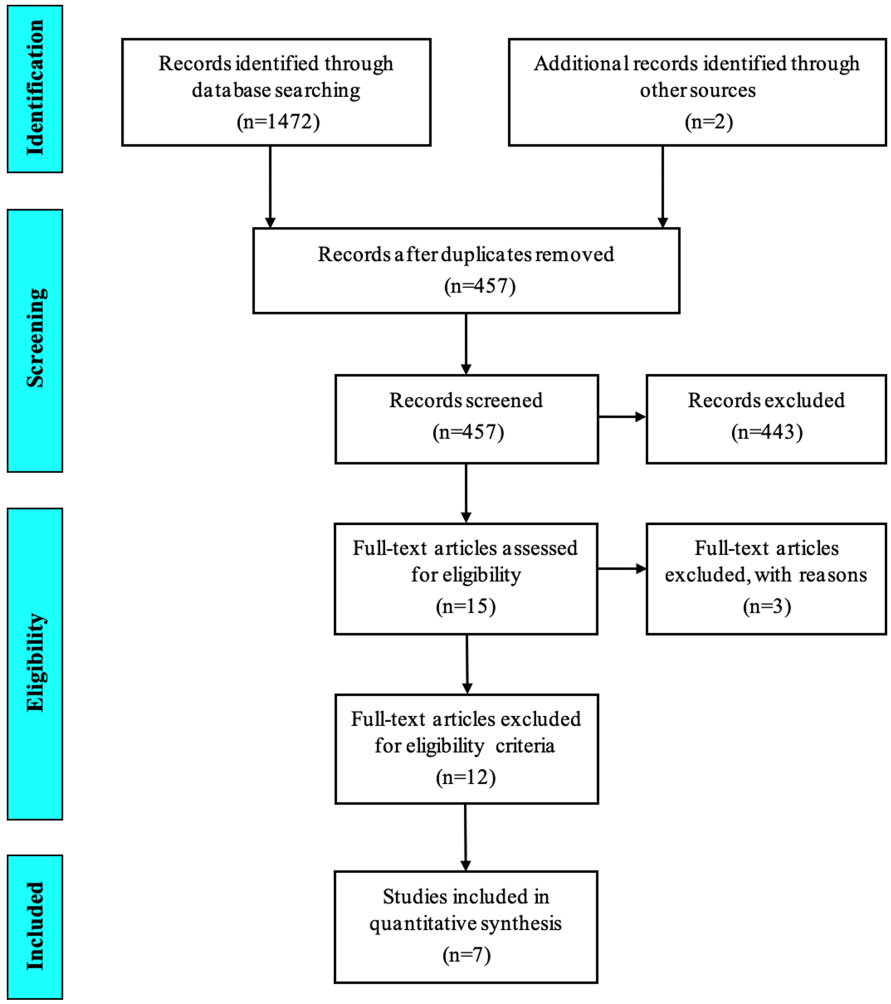

Figure 1 — Flowchart of the search strategy.

Results

Level of Evidence and Quality of Studies

All of the studies selected in the review were considered to have a low risk of bias (PEDro score ≥ 4; Table 2) following the previous systematic reviews.[40,41]

Characteristics of the Participants

The characteristics of the participants for the studies included in the review are shown in Table 1 (total sample size 161 participants, 10 women). Only 2 studies[30,35] included both men and women, while the remainder included only male cyclists.[27,28,31,36,37] The participants were simply described as competitive male cyclists,[31,36] male well-trained cyclists,[27,28] male trained cyclists,[30,37] and male and female trained cyclists.[30,35]

Characteristics of the Studies Selected

In the following sections, 2 established periodization models (BP and TP), training volume, and TID typically used to characterize competitive cyclists are introduced and the evidence base regarding the utilization of these models in the studies evaluated (Table 1). In addition, 3 of the 7 included studies compared TP[27] or BP models[28,30] with day-by-day (nonperiodized) programming.

BP Model Characteristics

Five studies reported data describing BP models performed by well-trained, and competitive cyclists.[28,30,35–37] The intervention period varied from 8 to 58 weeks in all studies.

Almquist et al[35] conducted a 12-week BP model using concentration of HIT, moderate-intensity training (MIT), and LIT (4-wk blocks). All LIT training was performed at low intensity, without supervision. For the MIT and HIT, all sessions were carried out using an effort-based approach. The participants were instructed to perform all sessions at the highest possible average power output, without reducing the power output after the first effort. Target RPE scores for each session type with gradually increasing effort for each interval (ie, MIT: 14–18 and HIT: 16–19) were provided as a guideline. Hebisz et al[30] alternated between 17-day blocks consisting of predominantly LIT and 11-day blocks of sprint interval training and high-intensity interval training (HIIT). LIT was performed at the power reached at the first ventilatory threshold measured during the incremental test. Sprint interval training was performed at maximal intensity (all-out effort) lasting 30 seconds, HIIT was performed at

Table 1 Characteristics of the Studies and Participants

	Participants			Training intervention		BP			TP			Day-by-day programming			
Authors	Age, y; n	Sex	Physiological/ performance factors	Design	Duration, wk	TID (% in h)	Approach	Volume, $h \cdot wk^{-1}$	TID (% in h)	Approach	Volume, $h \cdot wk^{-1}$	TID (% in h)	Approach	Volume, $h \cdot wk^{-1}$	Results
Rønnestad et al[36]	BP = 32 (7); n = 8 TP = 34 (6); n = 7	Male cyclists	VO_2max, $mL \cdot kg^{-1} \cdot min^{-1}$ BP = 62 (2) TP = 63 (3) GE, % BP = 19.6 (0.4) TP = 20.3 (0.8)	Experimental pre–post	12	LIT (73.7%) MIT (4.4%) HIT (9.4%) Other training (12%)	Polarized	9.9	LIT (82.6%) MIT (2.5%) HIT (8.7%) Other training (6.2%)	Polarized	10.76	—	—	—	Moderate superior effects of BP compared with TP training (ES range was 0.62–1.12) W2mM ↑(22% [14%] vs 10% [7%], respectively; $P = .054$)
Sylta et al[31]	38 (8); n = 63	Male cyclists	VO_2max, $mL \cdot kg^{-1} \cdot min^{-1}$ 61.3 (2.3) GE, % 19 (0.5)	Experimental pre–post	12	—	—	—	LIT (83.5%) MIT (14.2%) HIT (2.3%)	Pyramidal	10.1	—	—	—	VO_2peak ↑(3.9 $mL \cdot kg^{-1} \cdot min^{-1}$; $P = .05$) W4nM ↑(13 W; $P = .05$) GE ↓(−0.4%; $P = .05$) MAP ↑(12 W; $P = .05$) Power30s ↑(16 W)
Rønnestad and Hansen[37]	37; n = 1	Male cyclists	VO_2max, $mL \cdot kg^{-1} \cdot min^{-1}$ 73.8 W_{3mM}, $W \cdot kg^{-1}$ 3.6	Case study	58	LIT (67%) MIT (18%) HIT (10%) Heavy strength (5%)	Pyramidal	11.68	—	—	—	—	—	—	VO_2max relative and absolute ↑(18.5% and 12.3%). PPO ↑(19.7% and 14.2%) W_{3mM} ↑(36.1% and 29.3% absolute and relative increases)
Javaloyes et al[27]	TP = 37.6 (7.1); n = 8 HRV = 39.2 (5.3); n = 9	Male cyclists	VO_2max, $mL \cdot kg^{-1} \cdot min^{-1}$ HRV = 55 (7.6) TP = 52.2 (6.5) W_{VT2}, $W \cdot kg^{-1}$ HRV = 3.3 (1.2) TP = 3.3 (3.2)	Experimental pre–post	8	—	—	—	LIT (64%) MIT (27%) HIT (9%)	Pyramidal	8.76	LIT (66%) MIT (24%) HIT (10%)	Pyramidal	9.03	HRV group improved PPO ↑(5.1% and 4.5%; $P = .024$) W_{VT2} ↑(13.9% and 8.8%; $P = .004$) and 40TT ↑(7.3% and 4.5%; $P = .005$)
Javaloyes et al[28]	BP = 30.8 (10.5); n = 8 HRV = 28.1 (13.2); n = 7	Male cyclists	VO_2max, $mL \cdot kg^{-1} \cdot min^{-1}$ BP = 59 (6.2) HRV = 58.9 (5.6) W_{VT2}, $W \cdot kg^{-1}$ BP = 3.8 (2.6) HRV = 3.9 (11.3)	Experimental pre–post	8	LIT (54%) MIT (33%) HIT (13%)	Pyramidal	11.36	—	—	—	LIT (49%) MIT (39%) HIT (12%)	Pyramidal	11.01	HRV group improved VO_2max ↑(3% [3%]; $P = .03$) W_{VT2} ↑(17% [15%]; $P = .02$) W_{VT1} ↑(26% [8%]; $P = .01$); HRV vs BP W_{VT2} ↑(12% [12%]; $P = .02$)
Hebisz et al[30]	BP = 18.4 (1.6); n = 10 PT = 18.5 (1.9); n = 10	Male cyclists	VO_2max, $mL \cdot kg^{-1} \cdot min^{-1}$ BP = 60 (4.8) PT = 57.2 (5.8) W_{VT2}, $W \cdot kg^{-1}$ BP = 3.7 (4.5) PT = 3.7 (7)	Experimental pre–post	8	LIT (65%) MIT (0%) HIT (35%)	Polarized	8.75	—	—	—	LIT (59%) MIT (0%) HIT (41%)	Polarized	8.37	Increased in BP: VO_2max ↑(0.06%; $P < .01$ and 3.6%; $P < .05$) W_{max} ↑(0.06%; $P < .01$) W_{VT1} ↑(15%; $P < .05$) W_{VT2} ↑(11%; $P < .01$) Increased in PT:VO_2max ↑(13% and 12%; $P < .01$) W_{max} ↑(15%; $P < .01$) W_{VT1} (14%; $P < .05$). W_{VT2} ↑(11%; $P < .05$)

(continued)

Table 1 (continued)

Authors	Participants: Age, y; n	Participants: Sex	Participants: Physiological/performance factors	Training intervention: Design	Training intervention: Duration, wk	BP: TID (% in h)	BP: Approach	BP: Volume, h·wk^{-1}	TP: TID (% in h)	TP: Approach	TP: Volume, h·wk^{-1}	Day-by-day programming: TID (% in h)	Day-by-day programming: Approach	Day-by-day programming: Volume, h·wk^{-1}	Results
Almquist et al[35]	BP = 41.2 (9.3); n = 14 TP = 34.8 (8.8); n = 16	Male and women trained cyclists	VO_2peak, mL·kg^{-1}·min^{-1} BP = 54 (6.3) TP = 55.6 (11) W_{4mM}, W·kg^{-1} BP = 2.9 (0.4) TP = 2.9 (0.7)	Experimental pre–post	12	—	—	8.0	—	—	7.5	—	—	—	Both groups improved 5- and 40-min TT power by 9% (9%) ($P < .001$) and 8% (9%) ($P < .001$) MAP ↑(6% [7%]; $P = .001$) W_{4mM} ↑(10% [12%]; $P = .001$) and deterioration GE ↑(0.5% [1.1%]; $P = .026$) in a semifatigued state

Abbreviations: 40TT, power output during the 40-minute time trial; BP, block periodization; ES, effect size; GE, gross efficiency; HIT, high-intensity training; HIIT, high-intensity interval training; HRV, heart rate variability; LIT, low-intensity training; MAP, maximal aerobic power; MIT, moderate-intensity training; OP, periodization by blocks in a specific mesocycle order or in a mixed distribution; PPO, peak power output; PT, polarized training; SIT, sprint interval training; TID, training intensity distribution; TP, traditional periodization; TT, time trial; W_{max}, peak maximal power output; W_{2mM}, power output at 2 mmol·L^{-1} blood lactate concentration; W_{3mM}, power output at 3 mmol·L^{-1} blood lactate concentration; W_{4mM-}, power output at 4 mmol·L^{-1} blood lactate concentration; W_{VT1}, power output at VT1 intensity; W_{VT2}, power output at VT2 intensity; VO_2max, maximum oxygen uptake; VO_2peak, peak oxygen uptake.

Table 2 PEDro Ratings[a] and Oxford Evidence Levels of the Included Studies

Study	PEDro ratings 1	2	3	4	5	6	7	8	9	10	11	Total
Rønnestad et al[36]	No	0	0	1	0	0	0	1	0	1	1	4
Sylta et al[31]	Yes	1	0	1	0	0	0	1	1	1	1	6
Rønnestad and Hansen[37]	No	0	0	1	0	0	0	1	0	1	1	4
Javaloyes et al[27]	No	1	0	1	0	0	0	1	1	1	1	6
Javaloyes et al[28]	No	0	0	1	0	0	0	1	1	1	1	5
Hebisz et al[30]	No	1	0	0	0	0	0	1	1	1	1	5
Almquist et al[35]	No	1	0	1	0	0	0	1	1	1	1	6

Note: 1 = eligibility criteria were specified; 2 = subjects were randomly allocated to groups; 3 = allocation was concealed; 4 = the groups were similar at baseline regarding the most important prognostic indicators; 5 = measures of 1 key outcome were obtained from 95% of subjects initially allocated to groups; 6 = all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least 1 key outcome were analyzed by "intention to treat"; 7 = the results of between-group statistical comparison are reported for at least 1 key outcome; 8 = measures of at least 1 key outcome were obtained from more than 85% of the subjects initially allocated to groups. 9 = all subjects for whom outcome measures were available received the treatment or control condition as allocated;10 = the results of between-groups statistical comparisons are reported for at least 1 key outcome; 11 = the study provides both point measures and measures of variability for at least 1 key outcome. Abbreviation: PEDro, Physiotherapy Evidence Database.
[a]Items in the PEDro scale.

an intensity of 90% of maximal aerobic power measured during the incremental test. In the study of Javaloyes et al,[28] the training blocks consisted of 3 blocks of HIT (4 HIIT sessions per week), each followed by a block of LIT (4 LIT sessions and 1 HIIT session). The training sessions including LIT (first ventilatory threshold [VT_1] <VT_1), MIT (between VT_1 and second ventilatory threshold [VT_2]), and HIT (≥VT2). Rønnestad et al[36] conducted a 12-week training period characterized by a 1-week block of 5 HIT sessions, followed by 3 weeks of 1 HIT session per week. This sequence was repeated 3 times. The training sessions were divided into 3 heart rate zones: LIT (z1: 60%–82%), MIT (z2: 83%–87%), and HIT (z3: 88%–100%) of maximal heart rate. Rønnestad and Hansen[37] performed a single-athlete case study lasting 58 weeks. The first 8 weeks focused on blocks with LIT and MIT, with 1 HIT session per week. Each training block lasted 1 to 2 weeks; in total, the athlete performed 11 HIT blocks, 11 MIT blocks, 8 LIT blocks, and 19 recovery weeks. The training sessions were focused with LIT (z1: 60%–82%), MIT (z2: 83%–87%), and HIT (z3: 88%–100%) of maximal heart rate (Figure 2).

TP Model Characteristics

Four studies reported data describing TP performed by competitive and well-trained cyclists.[27,31,35,36] The intervention period varied from 8 to 12 weeks.

Almquist et al[35] used a weekly, cyclic progressive increase in training load of HIT, MIT, and LIT sessions for a duration of 12 weeks. Javaloyes et al[27] performed 8 training weeks consisting of 8 LIT sessions (<VT_1 intensity), 6 MIT sessions (between VT_1 and VT_2 intensity), 4 HIT sessions (at VT_2 intensity), and 4 HIIT sessions (>VT_2 intensity). Rønnestad et al[36] conducted, during 12 weeks, 2 HIT sessions (alternated between 6×5 and 5×6 min at zone 3) per week throughout the intervention period, interspersed with a relatively high volume of LIT sessions (a minimum duration of 1 h in intensity zone 1). The study of Sylta et al[31] consisted of three, 4-week mesocycles: week 1, medium LIT volume and 2 interval sessions; weeks 2 and 3, high LIT volume and 3 interval sessions; and week 4, reduced LIT volume (50% of the previous 2 wk) and 1 interval session. The sample was randomized to 3 training groups. The increasing HIT group performed interval sessions as 4×16, 4×8, and 4×4 minutes each 4 weeks; the decreasing HIT group in the reversed order and finally, the mixed HIT group in a mixed and balanced distribution of the 3 HIT prescriptions in all 3 mesocycles. The training sessions were focused with LIT (intensity zone 1: 60%–75% and zone 2: 75%–85%), MIT (intensity zone 3: 85%–90% and zone 4: 90%–95%), and HIT (intensity zone 5: 95%–100%) of peak heart rate (Figure 3).

Volume and TID

Training Volume. Training volume ranged from 7.5 to 10.76 hours per week in the TP [27,31,35,37] and from 8.75 to 11.68 hours per week in the BP.[28,30,35,36]

Training Intensity Distribution. TID was pyramidal in 4 studies,[27,28,31,36] 2 of them implemented a BP,[28,36] while only one study used the TP model.[27] Two studies described a polarized TID during BP model,[30,36] while Hebisz et al[30] described a polarized TID using a day-by-day program. The average TID was different for BP (LIT: 64.9%, MIT: 18.4%, HIT 16.8%, and other training: 8.5%),[28,30,35,36] TP (LIT: 76.7%, MIT: 14.5, HIT:6.6, and other training: 6.2%),[27,31,35,37] and day-by-day programming (LIT: 58%, MIT:31.5%, and HIT 21%).

Physiological and Performance Determinants Factors

$\dot{V}O_2$max/Peak Oxygen Uptake and Maximal/Peak Aerobic Power. Six studies reported data describing changes in $\dot{V}O_2$max.[28,30,31,35–37]

Rønnestad et al[36] reported relative changes in $\dot{V}O_2$max after the 12-week training period. BP achieved a larger relative improvement than TP (8.8% vs 3.7%, respectively, $P < .05$) and peak aerobic power output (W_{max}) during the last 2 minutes of the $\dot{V}O_2$max test increased in the BP group only (7.4%, $P < .05$). Sylta et al[31] evaluated the effects of different training blocks with variations in the progression of high-intensity sessions (increasing, decreasing, and mixed intensity) over 12-week training period. Peak oxygen uptake significantly improved by 3.8% to 5.8% (all $P < .05$) without differences between groups. They also reported an increase of 19% in maximal aerobic power ($P < .05$), for the increasing HIT intensity block only. Rønnestad and Hansen[37] reported changes in $\dot{V}O_2$max during 58 weeks focused on blocks

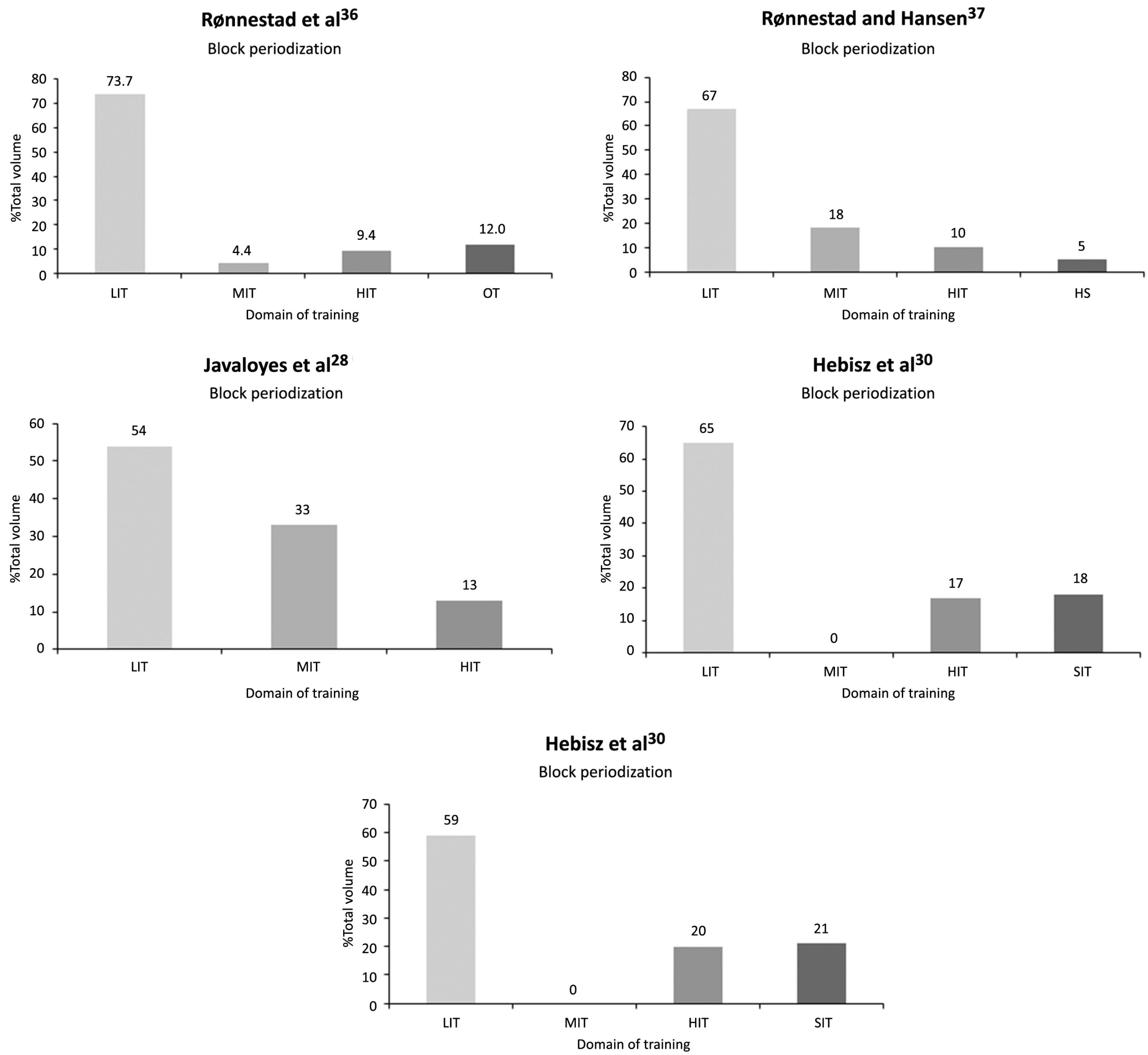

Figure 2 — Training intensity distribution for the block periodization model. HIT indicates high-intensity training; HS, heavy strength training; LIT, low-intensity training; MIT, moderate-intensity training; OT, other training; SIT, sprint interval training.

(LIT, MIT, and HIT), with increases in relative and absolute $\dot{V}O_2$max by 18.5% and 12.3%, respectively, in an elite cyclist. However, Javaloyes et al[27] did not find changes in $\dot{V}O_2$max during 8 weeks of TP, while in the study of Javaloyes et al,[28] the authors did not find changes with the BP model. In both studies, the groups who followed a training algorithm prescribed according to their heart rate variability (HRV) (HRV-guided group) improved their $\dot{V}O_2$max by 3%. Hebisz et al[30] compared the effectiveness of 8 weeks of BP and an overall polarized training program on aerobic capacity. $\dot{V}O_2$max improved by 14.8% and 6.7% ($P < .01$) for the polarized and block training program, respectively. W_{max} significantly increased in a similar way (6%) in both groups ($P < .01$). Finally, Almquist et al[35] found that peak oxygen u did not improve using either TP or BP models during a 12-week training period.

Power/Oxygen Consumption at Ventilatory Thresholds. Three studies evaluated the effects of these periodization models on ventilatory thresholds.[27,28,30]

Hebisz et al[30] found that BP and polarized training were effective strategies to improve the power reached at the first ventilatory threshold (16.9% and 16.4%, respectively [$P < .05$]) and VT_2 (12.8% and 16.4%, respectively [$P < .01$]). In addition, there was an increase of the VO_2 at VT_1 and VT_2 intensities for the polarized group (11.8% and 13.3%, respectively [$P < .05$ and

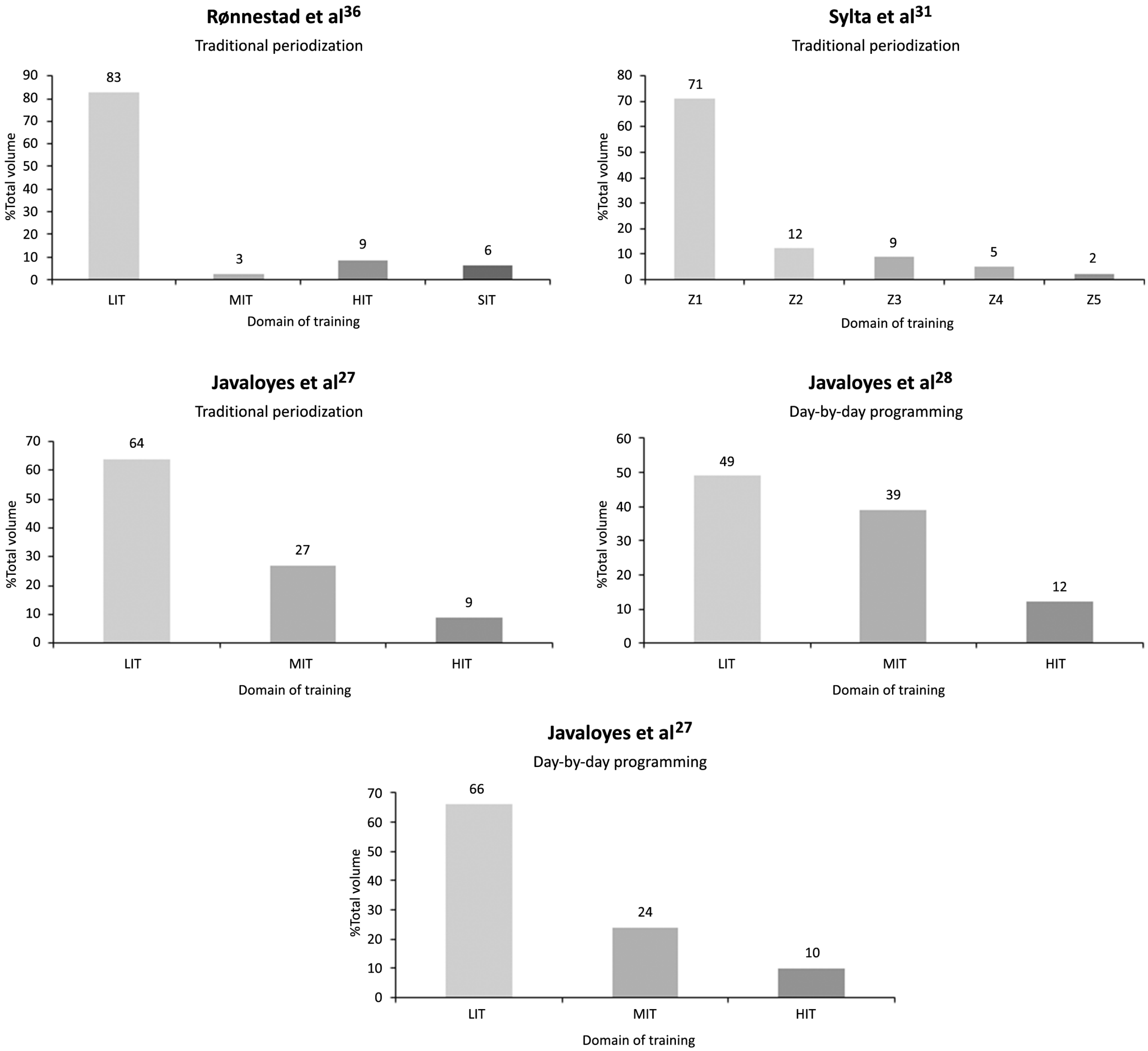

Figure 3 — Training intensity distribution for the traditional periodization model. HIT, high-intensity training; LIT, low-intensity training; MIT, moderate-intensity training; OT, other training; SIT, sprint interval training.

$P < .01$]), but only at VT_2 for the BT group (10.1% [$P < .01$]). Furthermore, Javaloyes et al[27] found beneficial changes in training prescribed according to their HRV-guided group at VT_1 (26%; $P = .01$) and VT_2 (17%; $P = .02$). However, the BP improved only at VT_2 intensity (12%; $P = .02$). In addition, Javaloyes et al[28] found significant changes in a HRV-guided group at VT_2 (13.9%; $P = .004$) but not for TP.

Power/Oxygen Consumption at Lactate Thresholds. Four studies reported power output and oxygen consumption at lactate thresholds.[31,35–37] Almquist et al[35] reported increased power output at 4 mmol·L^{-1} both in BP and TP (6% and 10%; $P = .001$). VO_2 at W4mM increased in both groups by 10% ($P = .001$) and the fractional utilization of VO_2 at W_{4mM} increased in both groups by 5% ($P = .026$). Furthermore, Rønnestad and Hansen[37] reported an increase in relative and absolute power output at 3 mmol·L^{-1} blood lactate of 13.6% and 29.3%, respectively, in a single cyclist following a BP. In addition, Sylta et al[31] found similarly improved power at 4 mmol·L^{-1} blood lactate by 5.8% and 5.9% ($P < .05$) with increasing (4 × 16, 4 × 8, and 4 × 4 min) and decreasing (4 × 4, 4 × 8, and 4 × 16 min) order of HIT session prescription across three, 4-week mesocycles. Finally, Rønnestad et al[36] reported a significant increase in power output at 4 mmol·L^{-1} blood lactate following BP and TP programs of 12 weeks (22% and 10%, respectively) without clear differences between groups due to large individual variation ($P = .054$).

Gross Efficiency. Three studies evaluated GE cycling.[31,35,36] Almquist et al[35] found an increase in GE in a semifatigued state in both TP and BP groups (0.5%; $P = .026$), without differences between groups (interaction effect: $P = .34$). In the study of Sylta et al,[31] the authors found that GE decreased using 3 types of HIT sequencing by 2.6%, 2.0% ($P < .05$), and 1.4% for increasing, decreasing, and mixed distribution of HIT sessions, respectively. The only distribution without significant differences between preintervention and postintervention was the mixed group. Rønnestad et al[36] reported that GE increased nonsignificantly by 2.9% in BP ($P = .12$), while GE in the TP group remained unchanged. However, the effect size of the relative improvement in GE revealed a moderate effect of performing BP training versus TP training (effect size = 1.10).

Discussion

The main finding of the present review is that there is currently no preponderance of evidence that a specific periodization model (TP or BP), or day-by-day programming model is generally more effective in trained road cyclists. Furthermore, no evidence has been found supporting the superiority of a specific periodization approach compared with day-by-day (nonperiodized) programming of training based on monitoring feedback. The relatively short duration of the interventions in periodization studies makes it difficult to draw firm conclusions regarding longer term changes in exercise and/or sports performance attributable to any particular periodization model. We cannot confirm that the studies followed a typical pattern of TP with only 12 weeks of intervention programming. In this sense, we can conclude they follow more a traditional "programming" than a "periodization." The typical linear periodized program builds aerobic capacity first through a period of high-volume/LIT before increasing the proportion of HIT.[29]

On the other hand, 5 studies reported data described as BP performed by well-trained and competitive cyclists.[28,30,35–37] BP in other sports have been found to be as equally, or more effective, for improving endurance capacity than TP,[42] and the high concentration of specific training session types within a limited number of days (blocks) seems to be effective for inducing adaptations in already well-trained athletes, if they maintain a manageable overall intensity distribution. This could be a reason why most available cycling studies of "periodization" have focused on the BP model. We can speculate that to be the case in a day-by-day program, in the same way. Javaloyes et al[27] performed 8 training weeks consisting of 8 LIT sessions, 6 MIT, and 8 high-intensity sessions (4 sessions at >VT2 and 4 sessions at ≥VT2). They found that a day-by-day program induces better overall results for cyclists than both strict BP programming and strict TP programming.[27]

Regarding training volume, the total volume per week ranged from 7.5 to 10.76 hours per week) in the TP, and from 8.75 to 11.68 hours per week in the BP groups evaluated. It seems reasonable to assume a weekly training volume between these ranges for improving the physiological determinants of cycling performance. Previous studies indicate that a high training volume is necessary for success in endurance performance.[29,43,44] However, the use of greater or lesser training volume will be affected by several factors (eg, training phases over a season, age, and athletes training status, etc), and for that reason, both volume and TID should be evaluated and understood in combination.[15] Finally, 2 BP interventions[28,37] used a pyramidal TID approach, while 2 studies[30,36] used a polarized TID approach. Regarding the TP interventions,[31,35,36] 2 studies[27,31] used a pyramidal TID approach and one[36] a polarized TID approach. Both polarized and pyramidal TID training have been found to be a very effective TID approaches to improve performance in endurance athletes.[33,45] In addition, several experts in endurance training have debated recently about which TID approaches could be better for endurances athletes.[46–49] It seems that large volumes of LIT (zone 1) are key to performance enhancement in endurance sports. However, it appears that the distribution of zones 2 and 3 of both approaches (used during endurance training periodization) will depend on the training phase or cycle, and the duration/distance of the event in competition. Most retrospective studies on well-trained to elite endurance athletes report a pyramidal TID, with a large proportion of high-volume to LIT approach. On the other hand, polarized TID is effective as well for some elite athletes during certain phases of the season.[33] For example, a TP organized with a hard day–easy day basis is recommended, incorporating a shift from a pyramidal TID used during the preparatory and precompetitive periods toward a polarized TID during the competitive period in highly trained and elite distance runners.[19] Regarding the shift from a pyramidal to polarized TID in cyclists, Zapico et al[50] did not find further improvement in power at VT1, VT2, or at VO_2max between 2 mesocycles with different TID approaches. In our case, both approaches are recommended for improving endurance performance in cyclists. Both pyramidal and polarized TID have in common a high relative volume of training below first lactate threshold/VT1, and an essentially dichotomous approach to prescribing/programming a sustainable balance of "low stress, fast recovery" and "high stress, delayed recovery" training sessions, with both threshold and HIT-type sessions falling into this "high stress, delayed recovery" category.

Finally, future research in cycling must focus on the periodization models in context of the total training completed during a season, because this sport includes many hours of competition at moderate and high intensities during a season. In addition, several recommendations can be made to help researchers. It is strongly recommended that future research complete a process involving: (1) describing the long-term global organization and training sequence of periodization model (ie, ≥12 wk) and (2) describing the long-term preparatory and competitive training periods.

All studies presented in this review have understandable and practical limitations, and thus the evidence they provided is often modest. It remains unclear whether a different training/periodization approach would yield better results. Besides, the wide variety of different interventions such as differences in volume and TID within these 7 studies can be seen as a limitation. It is conceivable that with current technological developments and digital data aggregation, a "multi-center" or "distributed sample" approach to investigating these questions would allow for longer intervention periods and larger sample sizes.

Practical Applications

To date, there is no evidence that a specific periodization model (8- to 12-wk duration) or day-to-day programming model is generally more effective in trained, nonelite road cyclists. Regarding training volume, it seems reasonable to recommend a range between 7 and 12 hours per week for this performance-level athlete, although developmental athletes aspiring to reach elite levels will typically train more. In addition, the inclusion of short MIT/HIT training blocks is recommended because competitions are performed at these intensities and can provide a specific overload stimulus. Ultimately, we recommend that the pyramidal and polarized TID approaches be combined and adjusted based on daily monitoring, depending on the training phase or cycle, to improve endurance performance in road cyclists.

Conclusions

We do not find evidence in the available research literature that a specific periodization model (8- to 12-wk duration) is consistently more effective in trained road cyclists. Neither do we find evidence that a "periodized" training model is superior to a day-by-day programming approach combined with a polarized or pyramidal TID ensuring adequate recovery from day to day. However, the short duration of the interventions in published periodization studies makes it difficult to draw firm conclusions regarding longer-term changes in exercise and/or sport performance attributable to any particular periodization model.

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