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Training intensity distribution on running time in amateur endurance runners: a scoping review

Distribución de intensidades de entrenamiento sobre el tiempo de carrera en corredores recreativos de resistencia: revisión de alcance

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Abstract

Problem: Intensity in endurance training is important for improving race time; its optimal handling in amateur runners has not been extensively studied. The polarized training intensity distribution (TID) model emerges as a possibility to reduce race time; however, effect of this model remains to be demonstrated compared to other TID models.

Objective: The objective of this study is to explore the current state of the evidence and its the gaps, according to the effect of the polarized TID model on race time in amateur runners compared to other TID models.

Method: A scoping review without date restrictions was carried out in PubMed, EBSCO, SciELO, LILACS, and Google Scholar. Randomized controlled studies, quasi-experimental studies, and case studies, which comprise polarized TID model in amateur runners on race time, were include.

Results: Five studies evaluated the effect on running time using the polarized TID model compared to other models in amateur runners; four of them did not show differences between groups in the race times in two, five, and ten km. Only one study showed significant differences in the race time at 21 km.

Conclusions: The model with polarized TID did not show significant differences in race time compared to other models, except for a case report in which the polarized TID was higher by 21 km compared to the threshold TID: 1 hour. 20 min. 22 seconds and 1 hour. 26 min. 34s, respectively. The scarce evidence found, the heterogeneity in the distances in the evaluated race time, the distribution of zones in the same TID, the duration of the interventions, and the monitoring of the loads, are the main limitations found in the studies. The polarized TID could contribute to adherence, lower perception of effort, and injury prevention. However, this must be tested in future studies.

Data availability
All relevant data is found in the article. For more information, contact the corresponding author.

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Authors contribution
Jerman Jesyd Cruz-González: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, review, and editing.
Víctor Hugo Arboleda-Serna: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, review, and editing.

Keywords:
Training intensity distribution; polarized training; amateur runners; race time; distance runners; threshold training; pyramidal training; high-intensity training; training zones; high volume and low-intensity training; endurance training.

Resumen
Problema: La intensidad en el entrenamiento de la resistencia es importante para mejorar el tiempo de carrera; su manipulación óptima en corredores recreativos no ha sido estudiada ampliamente. El modelo de distribución de intensidad del entrenamiento (DIE) polarizado emerge como posibilidad para reducir el tiempo de carrera. Sin embargo, falta demostrar su efecto comparado con otros modelos de DIE.

Objetivo: Explorar el estado actual de la evidencia científica y sus vacíos respecto al efecto del modelo de DIE polarizado sobre el tiempo de carrera en corredores recreativos, en comparación con otros modelos de DIE.

Método: Se realizó una revisión de alcance sin restricción de fechas en PubMed, EBSCO, SciELO, LILACS y Google Scholar. Se incluyeron estudios controlados aleatorios, estudios cuasiexperimentales y estudios de caso, que tuvieran como DIE el modelo polarizado en corredores recreativos sobre el tiempo de carrera.

Resultados: Cinco estudios evaluaron el efecto en el tiempo de carrera usando el modelo de DIE polarizado comparado con otros modelos en corredores recreativos; cuatro de ellos no mostraron diferencias entre grupos en los tiempos de carrera en dos, cinco y diez km. Solo un estudio mostró diferencias significativas en el tiempo de carrera en 21 km.

Conclusiones: El modelo con DIE polarizado no mostró diferencias significativas en el tiempo de carrera comparado con otros modelos, a excepción de un reporte de caso en el cual la DIE polarizado fue superior en 21 km comparado la DIE umbral: 1 hora. 20 min. 22 s y 1 hora. 26 min. 34 s, respectivamente. La escasa evidencia encontrada, la heterogeneidad en las distancias en el tiempo de carrera evaluado, la distribución de zonas en una misma DIE, la duración de las intervenciones y la monitorización de las cargas son las principales limitaciones encontradas en los estudios. La DIE polarizado podría contribuir a la adherencia, a una menor percepción del esfuerzo y a la prevención de lesiones. No obstante, esto debe ser probado en estudios futuros.

Palabras clave:
Distribución de intensidades del entrenamiento; modelo polarizado; corredores recreativos, tiempo de carrera; atletismo; corredores de fondo; modelo umbral; modelo piramidal; entrenamiento de alta intensidad; zonas de entrenamiento; alto volumen y baja intensidad; entrenamiento de resistencia.

Introduction
In endurance training, several studies have been carried out to analyze the training intensity distribution (TID), seeking to determine the ideal volume and intensity to generate greater adaptations. The TID models are defined by the total percentage of time spent in each training zone during a microcycle or mesocycle. There are

different models of training zones, with three zones being the most widely used by scientific evidence, which are based on the three-phase model [1,2]. However, there are models with two, four, five and seven zones [3,4]. These zones are defined by several authors considering physiological markers such as ventilatory thresholds and blood lactate concentration. Zone one, or low-intensity training, is characterized by exercise at an intensity below the first ventilatory threshold (<VT1) or lactate threshold number one. Zone two or moderate-intensity training, or threshold level training, is at the intensity between lactate and ventilatory thresholds one and two (VT1 and VT2). Zone three, or high-intensity training, is located at an intensity above lactate and ventilatory threshold two (>VT2) [5–7].

The TID models identified in the literature are the following:

Polarized training model

It consists of a TID of 75-80% of the total time of the training program in low-intensity zones (<VT1), and 0-20% in the high-intensity zone (>VT2), with little time (0-5 %) in the moderate area (between VT1 and VT2) [3,8–11].

Threshold training model

The TID is centered in a proportion >20% of the total time of the training program between VT1 and VT2, with a lower proportion in zones one and three [8,11,12].

Pyramidal Training Model

This TID consists of a high percentage of the total training program time in zone one, usually around 80%, with a smaller proportion in zone two, and even less in zone three [8,11–13].

High-intensity training model

The highest percentage of TID is found in zone three, around 50% and 70% of the training time [3,8,11].

High volume, low-intensity training model

This TID is developed in zone one, with a percentage of the training time of 100% or very close to it [3,8,14].

These TID models have been studied in different sports such as athletics [6,7,9,14–19], triathlon [10,14,20,21], cross-country skiing [14], speed skating [22], and swimming [23]. These studies have been conducted in order to quantify the optimal internal and external loads, as well as methods to improve performance [24]. In the case of athletics, the measurement of performance is mainly determined by the running time over a given distance. However, the optimal volume and TID have been difficult to agree on [5,8].

Although there is evidence to determine the TID in athletes, these have had difficulties due to the heterogeneity of the methods of quantification of the training zones [8]. Heart rate, lactate threshold, perception of effort, race pace, percentages of speed at which athletes cover a given distance or maximum aerobic speed, inidividual specific race pace, and critical power have been used through laboratory and/or field tests [5,25]. However, it has been shown that the same training load can result in a different TID model depending on the method used to quantify the time in each intensity zone [12].

In the case of recreational athletes, taking into account the growth of popular races and the massive participation of amateur athletes worldwide [26], interest in the effectiveness of

TID has led to some research being carried out prospectively in the last decade in amateur athletes due to the mass phenomenon of popular races. In addition, with the increasing use of cardiac monitors and other elements of quantification in recreational sports [24], it is necessary to identify the optimal TID to provide guidance for the effective use of these tools. For now, the optimal TID in both elite athletes, but even more so in amateur athletes, is unknown and remains a source of debate [4,8,12–14].

Regarding the sports levels of runners, there are no clear parameters to determine when an athlete is recreational. The evidence has determined it by training frequency between 3-4 d/wk [17], exercise volume of 4h/wk [9], 3.2h/wk [7], <5h/wk [15]; also by physiological parameters such as a maximum oxygen consumption (VO2max) around 45±5.8 ml/min/kg [16] and by time in race distances less than 1h:40min:00sec in half marathon [19]. It should be emphasized that for the recreational athlete, aspects related to work occupation, time availability for practice, and rest time are not identified, which are aspects that affect the optimal TID, since for the elite athlete, running is a professional activity [27].

Although scientific evidence is scarce and this in turn has few studies where the main outcome is running time, there is consensus that the highest percentage of training (~80%) should be performed at low intensities [4,9,28–30], as well as that emphasis in high intensity is a mistake that can lead to overtraining and the appearance of injuries [3,4,20], triggering adverse effects such as fatigue [3,8], loss of sports performance and motivation [3,9], eating disorders, depression, and psychosomatic disorders [3], which would finally affect endurance performance and therefore improvements in race time [3,8,9,20].

It is important to generate strategies to guide exercise in this population, since the TID is an essential tool for planning exercise and obtaining better adaptations, especially in the race time [8,24,31].

This scoping review intends to show the current state and the gaps of the scientific evidence regarding the polarized TID model and its effects on race time in amateur runners compared to other TID models, thus providing a starting point for defining what would be the optimal TID for this population.

Materials and Methods

We concluded that a scoping review was the most appropriate to address the objective of this study, since it provides an overview of the volume and distribution of scientific evidence, allows the inclusion of diverse research designs —as long as they contribute to solving the research objective—, and highlights where further studies are warranted.

Taking into account the above, the present scoping review was designed based on the four arguments proposed by Arksey and O'Malley [32] to justify initiating such a review, which are: 1) to examine the extent, scope and nature of the research activity, 2) to determine the importance of conducting a systematic review, 3) to summarize and disseminate the results of the research, and 4) to identify gaps in the existing evidence. In addition, the PRISMA checklist was considered in its extension for scoping reviews [33]. Likewise, the five steps proposed by Arsksey and O'Malley to conduct a scoping review were followed [32]: identifying the research question, identifying the relevant studies, selecting the studies, charting the data, and collating, summarizing and reporting the results.

According to the previous steps, we started with the research question which was formulated as "What is the effect of the polarized TID model compared to other TID models on running time in recreational runners?", where the primary outcome defined was running time, since this is the main parameter to measure performance in recreational or elite runners [34].

To identify relevant studies, a review of the literature without date and language restrictions was carried out in PubMed, EBSCO, SciELO, LILACS, and Google Scholar databases and was conducted between August 2021 and May 2022. Two reviewers conducted the searches using the following search strategies: first strategy "training intensity distribution" AND "recreational runners" OR "long distance runners" OR "amateur runners" AND "run" OR "running" AND "polarized training"; second strategy "training intensity distribution" AND "distance runners" OR "long distance runners" OR "middle-distance runners". Third strategy "polarized training" AND "running" OR "marathon running".

Randomized controlled trials (RCTs), Non-RCTs, and case studies involving the polarized TID model in recreational runners and evaluating running time were included. Observational studies, studies with elite athletes, and other endurance sports were excluded.

Once all the studies had been identified in the databases, duplicate articles were removed. The remaining articles were analyzed by title and abstract. The chosen studies were reviewed at full text to determine which would be included in the scoping review. Data extracted from the included texts were analyzed by the reviewers using a standardized format with the following information: study authors, year of publication, study design, population and sample, interventions and their duration, outcome variables, race distance, assessment instruments used, and results of outcomes assessed. The included studies were organized into two categories according to the comparator TID model: the first category was composed of studies comparing the polarized TID model with the threshold TID model; the second one was composed of studies comparing the polarized TID model with the high-intensity TID model, and with the high-volume low-intensity TID model. The results were presented by identifying the effects on running time between the polarized TID model compared to the other TID models.

Results

This process resulted in the identification of 442 articles. After duplicates were removed, 112 were examined by title and abstract, of which 11 were selected for full text reading. Finally, five studies were selected (see Figure 1). Only studies that compared the effect of polarized TID model with other TID models on running time in recreational athletes were included in this scoping review.

The studies included a total of 137 subjects, 101 males and 36 females. Table 1 shows detailed information regarding the research designs, the population and sample, the comparison of the TID models analyzed, the duration of the interventions, the running distances evaluated, the zone distributions of each TID, and the results of the different TID models on running times.

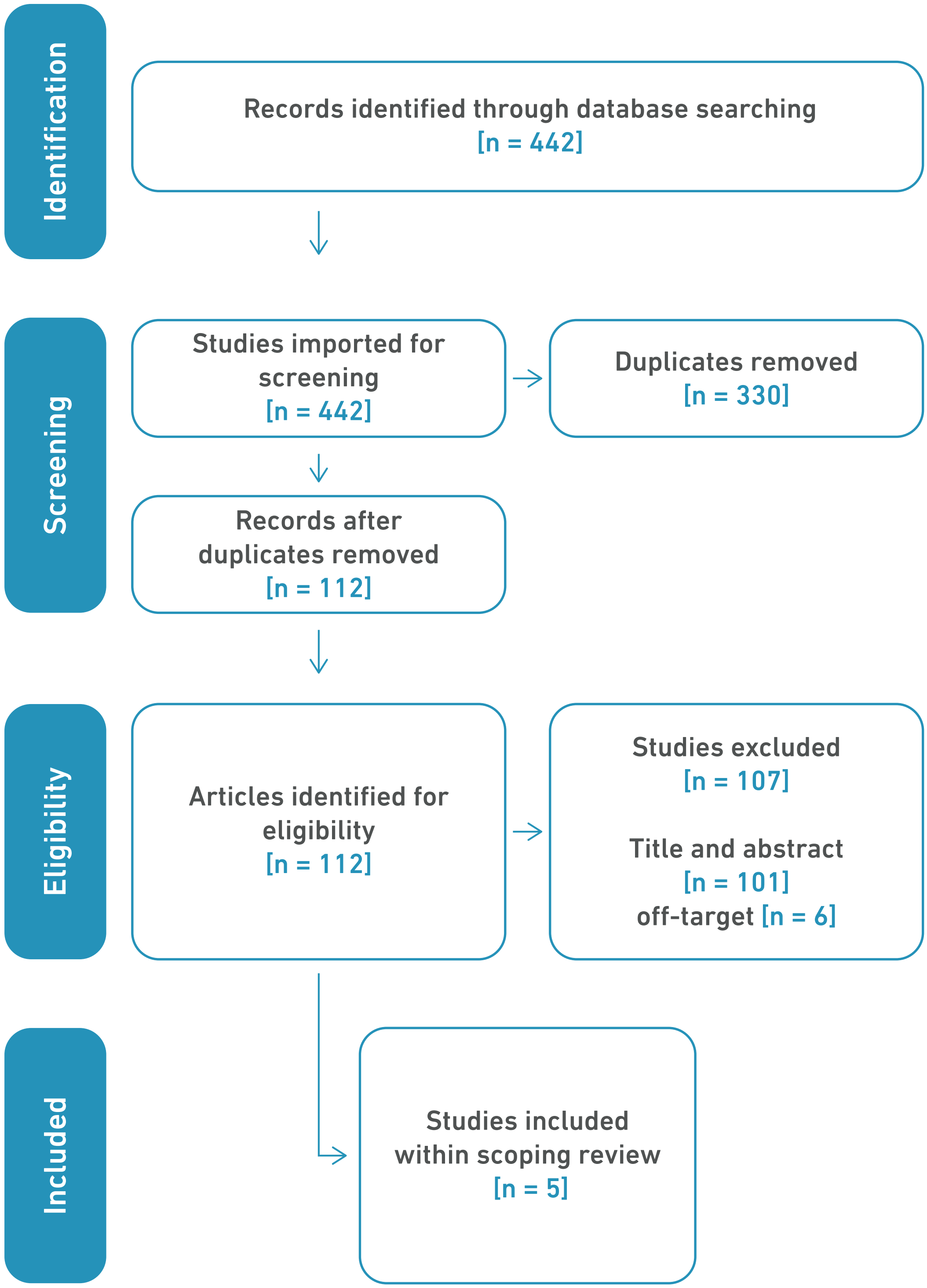

Figure 1. Flowchart of the systematic screening process (PRISMA)

Table 1. Effect of TID models on race time in amateur athletes

Authors	Year	Design	Population /sample	TID Interventions	Duration	Race Distance	Polarized TID	TID Comparison group	Race time Results
Carnes & Mahoney [15]	2018	RCT	Amateur Runners/26	Polarized vs. high-intensity	12 weeks	5 km	Zone 1 (73.8±14.8%) Zone 2 (11.1±14.1%) Zone 3 (15.0±6.4%)	Zone 1 (46.2±11.1%) Zone 2 (15.4±14.9%) Zone 3 (38.5±14.2%)	Polarized TID 22 min. 53 s ± 2 min. 12 s High intensity TID 22 min. 58 s ± 2 min. 48 s. (p>0.05)
Festa et al. [7]	2020	RCT	Amateur Runners/38	Polarized vs. threshold	8 weeks	2 km	Zone 1 (78±9.2%) Zone 2 (3.1±1.3%) Zone 3 (18.9±4.6%)	Zone 1 (38.7±9.6%) Zone 2 (48.8±12.8) Zone 3 (12.5±5.7%)	Polarized TID 08 min. 23 s Threshold TID 08 min. 23 s (p>0.05)
Muñoz et al. [9]	2014	CET	Amateur Runners/30	Polarized vs. threshold	10 weeks	10 km	Zone 1 (72.9±5.6%) Zone 2 (13.5±5.6%) Zone 3 (13.6±4.3%)	Zone 1 (46.8±15.2%) Zone 2 (37.3±16.1%) Zone 3 (15.8±4.1%)	Polarized TID 37 min. 19s ± 4 min. 42 s Threshold TID 38 min. 00 s ± 4 min. 24 s (p>0.05)
Muñoz & Valera-Sanz [18]	2018	Case Report	Amateur Runners/1	Polarized vs. threshold	38 weeks	21 km	Zone 1 (83.3±8.1%) Zone 2 (13.6±6.6%) Zone 3 (3.2±4.7%)	Zone 1 (63.5±10.8%) Zone 2 (32.3±10.6%) Zone 3 (4.2±3.7%)	Polarized TID 1 hora 20 min. 22 s Threshold TID 1 hora 26 min. 34 s (p<0.05)
Zinner et al. [16]	2018	RCT	Amateur Runners/42	Polarized vs. high-intensity Polarized vs. high-volume and low-intensity	8 weeks	5 km	Zone 1 (69.7±16.3%) Zone 2 (13.4±16.4%) Zone 3 (16.9 ±11%)	High-intensity: Zone 1 (39.3 ±1.6%) Zone 2 (20.5±23.7%) Zone 3 (40.2±23.3%) High-volume and low-intensity: Zone 1 (93.7 ±8.8%) Zone 2 (6.3±8.8%) Zone 3 (0%).	Polarized TID 25 min. 27s ± 3 min. 34s High intensity TID 24 min. 39s ± 3 min. 16s (p>0.05) High-volumen and low-intensity TID 26 min. 15s ± 6 min. 12s (p>0.05)

Polarized TID model compared to threshold TID model on race time

Three studies compared the effect of the polarized TID model with the threshold TID model on running time [7,9,18]. Muñoz et al. [9] compared the effect of a 10-week polarized TID and a 10-week threshold TID training program in 30 amateur runners on 10 km race time. The polarized model was made based on the following zones and percentages of time in the respective zones: zone one 72.9±5.6%, zone two 13.5±5.6%, and zone three 13.6±4.3%. Consequently, the threshold model was stablished as follows: zone one 46.8±15.2%, zone two 37.3±16.1%, zone 3 15.8±4.1%. The results showed no statistically significant differences ($p>0.05$) between the polarized group and the threshold group (37 min 19 s ± 4 min 42 s vs. 38 min 00 s ± 4 min 24 s).

A RCT [7] compared the effect of a training program with polarized TID and another called "Focused Endurance Training", in which the TID occurs in a threshold model. The TID of the polarized model in each zone was: zone one 78±9.2%, zone two 3.1±1.3%, zone three 18.9±4.6%. For the focused endurance training program, the threshold TID presented the following distribution: zone one 38.7±9.6%, zone two 48.8±12.8%, zone three 12.5±5.7%. Both programs lasted eight weeks and were carried out in 38 amateur runners, in which the performance of the 2 km race was evaluated; it was carried out by determining the average speed in 2 km. The results obtained when comparing the polarized TID model and the focused endurance training, after the eight weeks of intervention were 14.3 km h^{-1}, without statistically significant differences between groups ($p>0.05$). It should be noted that for this review the conversion of average speed to race time was made since the latter correlates to the outcome of interest in this review, which corresponds to a 2 km time of 08 min. 23 sec.

In a case report [18], the authors analyzed the effects of two different TID training programs on an amateur athlete in his half-marathon time. To do this, they trained the athlete for two seasons of 19 weeks each: the first under the threshold TID model and the second with the polarized TID model. The threshold program was developed as follows: zone one 63.5±10.8%, zone two 32.3±10.6%, and zone three 4.2±3.7%. For its part, the polarized TID model made the following distribution: zone one 83.3±8.1%, zone two 13.6±6.6%, and zone three 3.2±4.7%. The results indicated statistically significant improvements ($p<0.05$) in the 21 km race time in the season with the polarized TID model (1 hour 20 min 22 s) compared to the season carried out under the threshold TID model (1 hour. 26 min. 34 s).

In summary, the results show non-significant differences between the polarized group compared to the threshold TID model at the 21 and 10 km distances [7,9]. Only one case report [18] shows significant differences at the 21 km distance. Although the differences were not statistically significative, in the study by Muñoz et al. [9], the polarized TID model led to a running performance improvement of ~2%, which is important to consider even in non-elite runners.

Effects of polarized, high-intensity, and high-volume and low-intensity TID models on race time

Two studies compared the effect of the polarized model with the high-intensity TID model on running time [15,16] and one of these studies also compared the polarized model with the high-volume, low-intensity model [16]. Carnes & Mahoney [15] randomized 26 amateur runners to either a polarized TID training program or a program they called CrossFit endurance (CFE), which utilized concurrent training and has a TID that corresponds to the high-intensity model. The athletes were intervened for 12 weeks and the effects of both training programs on the 5 km race time were compared. It should be noted that the analysis of the results was carried out only on 21 runners who fulfilled more than 89% of the intervention. The TID for each of the interventions was as follows: the polarized TID model was in zone one at 73.8±14.8%, in zone two at 11.1±14.1%, and zone three at 15.0±6.4%; for the CFE, the high-intensity TID presented 46.2±11.1% in zone one, 15.4±14.9% in zone two, and 38.5±14.2% in zone three. The results showed no statistically significant differences ($p>0.05$) for the 5 km time when the polarized and the CFE with high-intensity TID models were compared (22 min 53 s ± 2min 12 s vs. 22 min 58s ± 2min 48 s, respectively).

Another RCT [16] compared the effect of training programs with three TID models, polarized, high intensity, and high-volume and low-intensity in 42 amateur runners, on the time in 5 km. The intervention was divided into three mesocycles as follows: mesocycle one, lasting four weeks with the same TID; followed by a three-week mesocycle where participants were randomly assigned to one of the three TID models described above; finally, the third mesocycle consisted of a week called "tapperin" or recovery, in which the same TID was used for all participants. In the intervention mesocycle with the three TID models, the percentages of total training time in zones were as follows: for the polarized TID model, zone one was 69.7±16.3%, zone two was 13.4±16.4%, zone three 16.9±11%; in the model with high-intensity TID, zone one 39.3 ±1.6%, zone two 20.5±23.7%, zone three 40.2±23.3%; and for the model with high volume and low-intensity TID, zone one 93.7 ± 8.8%, zone two 6.3 ± 8.8%, zone three 0%. The results found no statistically significant improvements ($p>0.05$) between the polarized TID model and the other TID models. The 5 km race time for the polarized TID model was 25 min. 27 s ± 3 min. 34 s, for the model with high-intensity TID it was 24 min. 39 s ± 3 min. 16 s, and for the high-volume, low-intensity TID model it was 26 min. 15s ± 6min. 12 sec. In summary, no significant differences were found between the different TID models.

Evidence gaps

The gaps found in the literature were the lack of studies comparing the polarized TID model with the pyramidal TID model in recreational athletes, as well as the lack of similar studies, both in the TID models compared and the distances evaluated. Nor was a standard parameter identified to define the characteristics of the recreational athlete. Finally, the level of physical activity of the athletes outside training, strength training, and nutritional patterns were not quantified.

Discussion

The main findings indicate that the little scientific evidence found [7,9,15,16,18] shows that the polarized TID model in most studies (4/5) is not superior in improving race times concerning the other TID models [7,9,15,16]. No significant differences were found between the groups. However, the limitations of the studies focus on the small sample sizes, the heterogeneity in the distances in the race times evaluated, the duration of the programs, and the distribution of percentages of training in the zones despite being the same TID.

In the studies found, the TID model most compared with the polarized TID model was the threshold TID model [7,9,18] although it has been evidenced that elite and highly trained athletes follow a pyramidal and/or polarized TID model [5,8,25]. Therefore, it would be important to compare the latter two in recreational athletes.

The distances evaluated (5km, 10km and 21km) are mostly within the distances regulated by the World Athletics [35], with the exception of one distance (2km), which is important given that popular races run the same distances.

Festa et al. [7] included the distance in 2 km seeking to have some outcome variable in the race time. However, they state that it should be tested in longer distances since the improvements may not possibly be as visible and are not as representative for long-distance runners in this distance. The authors recommend the evaluation of the effect of half marathon or marathon in future studies. Only one case report [18] showed a significant improvement in the half-marathon distance. Therefore, it would be important to carry out studies with more robust designs that support this result and can test whether the TID affects race times at different distances.

There is consensus in the literature for the determination of three intensity zones (low, moderate, and high) based on physiological parameters. The most popular tests for their determination are incremental tests with gas analysis evaluation and blood lactate concentration measurements [6,7,9,12,14–19]. However, the difficult access and high costs of these tests in recreational athletes are highlighted. Therefore, it would be very useful to evaluate the reliability and accuracy of the devices used in daily training to facilitate such access and monitoring of loads in a wide population, and thus facilitate the follow-up and control of training [24].

It is important to consider the control of the management of the intensities of the runners for the development of future studies. Muñoz et al [9] report in their study on the exclusion of runners who did not strictly comply with the prescribed training intensities. Therefore, it is important to emphasize that in most of the investigations carried out, the training intensity was controlled by heart rate monitoring. However, it has been reported that several factors influence the heart rate - load relationship, which changes between individuals (around six beats per minute) and may be conditioned by external effects such as the training level, environmental conditions, sleep, hydration status, altitude, medications, among others. The use of heart rate reserve or its variability is proposed for load monitoring [36]. For this, some studies propose using the running pace as a marker of intensity more than physiological markers (oxygen consumption, blood lactate, ventilatory thresholds, among others) or propose the use of these physiological markers in pre-seasons and the use of the running pace as an indicator of intensity in the stages of specific and competitive preparation [12].

The authors refer that one of the advantages of the polarized TID model is the prevention of injuries and the control of overtraining [9,18], which would generate more adherence to this type of TID in amateur athletes, although this relationship with the best race times are yet to be evidenced and verified.

Conclusions

In the scientific evidence found, the polarized TID model did not show significant differences compared to other TID models such as the threshold model, the high-intensity model, and the high volume and low-intensity model regarding race time. No evidence was found comparing the polarized TID model with the pyramidal TID model, which is important for future research, since the pyramidal model has been the most used by athletes at other levels.

The small number of studies carried out, the small sample sizes, the heterogeneity in the distances in which the running time was evaluated, the distribution of the training zones in the same TID, as well as the monitoring of the load, are limitations referred by the authors that should be treated in future studies.

Although the results of the polarized TID model compared to the other TID models did not show significant differences, the polarized TID model could contribute to adherence to training, fundamentally for two reasons: the possibility of having a lower perception of effort and of preventing injuries, important factors in the continuity of the training process progressively avoiding over-training, a situation that is presumed to be very frequent in amateur athletes and would significantly affect the improvement of race times.

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