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Original Article

Training intensity distribution and performance of a recreational male endurance runner. A case report

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Abstract
The polarized training intensity distribution model (PTM) has demonstrated to achieve larger improvements than lactate threshold model (LTM) in elite and well-trained endurance athletes. However, there is a lack of knowledge about the effectivity of PTM with novice recreational runners. This research aimed to compare the impact of LTM *vs* PTM on a novice recreational runner's performance. The athlete (age 32 y, body mass 73 kg, height 179 cm, basal HR 43 bpm, Σ6 skinfolds 51.6 mm) trained two consecutive seasons following a LTM and a PTM (~63%/32%/5% *vs* ~83%/14%/3% for zones 1, 2 and 3, respectively). In the 6th week of each season, a maximal test was performed to determine the physiologic thresholds and the maximum aerobic speed (MAS). During the intervention, training intensity was daily controlled based on HR. A half marathon race was performed at the end of each season to evaluate running performance. Training load was quantified based on TRIMPs model and the rate of perceived exertion (RPE) was recorded after each training session. Half marathon performance improved after the PTM season. Weekly TRIMPs were significantly higher during the 1st season. Training time and % of training time in zones 1 and 2 were significantly different between seasons. No differences were found between seasons for the weekly training time, nor for the RPE. PTM leads to a greater performance in a novice recreational runner. Nevertheless, a minimum training background and training time availability could be necessary to successfully apply this model in novice endurance athletes.
Key Words: *endurance training, polarized training model, lactate threshold model, running performance*

Introduction

In the last two decades, the participation of recreational runners in running events (e.g. 5 km, 10 km, half marathon and marathon) increased worldwide year after year. However, many of these athletes follow themselves "standard" training programs in an attempt to successfully finish the races or improve their personal best.

Optimal endurance performance depends on the proper manipulation of the different training variables (i.e. intensity, duration and frequency) of a training program (Seiler, 2010). In recent years many studies have suggested that training intensity distribution plays a key role on endurance training adaptations not only in elite (Ingham, Fudge & Pringle, 2012; Laursen, 2010; Orie, Hofman, de Koning & Foster, 2014; Seiler, 2010; Seiler, Haugen & Kuffel, 2007; Seiler & Kjerland, 2010), but also in well-trained recreational athletes (Esteve-Lanao, Foster, Seiler, & Lucia, 2007; Esteve-Lanao, San Juan, Earnest, Foster, & Lucia, 2005; Muñoz, Cejuela, Seiler, Larumbe, & Esteve-Lanao, 2014; Muñoz, et al., 2014b; Neal, et al., 2013; Stöggl & Sperlich, 2014) of various endurance-sports modalities.

In this regard, the scientific literature has identified two well-differenced training models based on intensity distribution. Conventionally, the traditional training intensity distribution is represented by the so-called *lactate threshold model* (LTM), which is characterized by a high amount of training time expended in zone 2 (i.e. between physiologic thresholds) (Esteve-Lanao, et al., 2007; Neal, et al., 2013). On the other hand, the *polarized training model* (PTM) is characterized by the accumulation of the most training time in zone 1 (i.e. below the first physiologic threshold) and a minor training time in zone 3 (i.e. above the second physiologic threshold), with an intensity distribution of ~75%/5%/20% in zones 1/2/3, respectively (Esteve-Lanao, 2007). On this point, it has been consistently demonstrated that PTM is more effective than LTM for improving endurance performance in different endurance-sports modalities (Laursen, 2010; Seiler, 2010), which could be linked to the physical activity pattern our ancestors had for survival (Boullosa, Abreu, Varela-Sanz, & Mujika, 2013). One of the mechanisms of this greater effectiveness may be based on avoiding the disturbances in the autonomic nervous system (ANS) (Seiler, et al., 2007) and therefore minimizing the possibility of developing the so-called *overtraining syndrome* (Foster, 1998).

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Even though the benefits related to the PTM have been proved in well-trained recreational athletes (Esteve-Lanao, et al., 2005; Esteve-Lanao, et al., 2007; Lucia, Hoyos, Pérez & Chicharro, 2000; Mujika, et al., 1996; Muñoz, et al., 2014a; Stöggl & Sperlich, 2014) and in young, healthy, and physically-active individuals (Varela-Sanz, Tuimil, Abreu, & Boullosa, 2017) , there is a lack of knowledge about what is the most effective intensity distribution model for recreational runners with little training experience. In connection with this, it was suggested that recreational athletes tend to train harder the "easy" days of training and easier the "hard" ones, contrary to the coach's scheduled training program (Foster, Heimann, Esten, Brice & Porcari, 2001). For this reason, some authors have suggested that the LTM could be a better option in novice recreational athletes with a poor training background (Londeree, 1997), especially when training weekly frequency is <3 days (Esteve-Lanao, 2007).

Therefore, the aim of the present study is to shed light on this issue for trainers and practitioners, comparing the impact of two different training intensity distribution models (i.e. lactate threshold *vs* polarized training) on a novice recreational runner's physiological variables and his half marathon performance in two consecutive seasons.

Material & methods

Experimental Approach to the Problem

The presented data correspond to two periods of 19 weeks in two consecutive seasons. Each day of training was recorded in the athlete's personal log of training. The participant slept ~8 h per day and there was no control for diet patterns.

During the 1st season, the training intensity distribution tended to follow a LTM, with emphasis in moderate-to-high intensity training (63.5±10.8%/32.3±10.6%/ 4.2±3.7% for zones 1/2/3, respectively). The training intensity distribution during the 2nd season was based on a PTM, and was characterized by the accumulation of a high training volume under the first physiologic threshold, combined with moderate- and high-intensity training above the second physiologic threshold (83.3±8.1%/13.6±6.6%/3.2±4.7% for zones 1/2/3, respectively).

In order to determine the athlete's performance, a half marathon race was completed in each season at the same period of time and at the same phase of the season (i.e. 19th week of training). With the purpose of confirming that the athlete started the 2nd season without any residual training effects derived from the previous season, he took part in a half marathon race (6th week of training of the 2nd season) for evidencing his performance.**Subject**

A novice recreational male endurance runner (age 32 y, body mass 73 kg, height 179 cm, basal HR 43 bpm, Σ6 skinfolds -triceps, subscapular, suprailiac, abdominal, quadriceps, and medial calf- 51.6 mm) with more than 6 years of experience as recreational endurance cyclist (~2 days per week without a systematic training program) and without any experience in running at the beginning of the present study, took part in this case study after signing a written informed consent. This study was conducted in accordance to the Declaration of Helsinki for Human Research (2013).

Physiological test

On the 4th week of training of each season, a maximal incremental discontinuous running test was performed on a treadmill at a gradient of 1% to correct for the air resistance effect (Jones & Doust, 1996). The initial velocity was set at 10 $km·h^{-1}$ with increments of 1 $km·h^{-1}$ each 4 min (i.e. 3 min work-stage + 1 min rest) until volitional exhaustion. Aerobic (AeT) and anaerobic (AnT) thresholds were determined through the measure of blood lactate concentration [La^{+}] (Lactate Pro2, Arkray Inc, Amsteleveen, Netherlands) as previously suggested (López-Chicharro, et al., 2004), and associated with heart rate (HR) (Polar V800, Polar Electro Oy, Finland) to prescribe individualized exercise training intensities in the 3 exercise intensity zones (i.e. zone 1, HR below the AeT; zone 2, HR between AeT and AnT; zone 3, HR above AnT) (Esteve-Lanao, et al., 2005; Esteve-Lanao, 2007). Maximal aerobic speed (MAS) was established as the speed attained in the last completed 3 min work-stage. Estimated VO_2max was also calculated through the Léger and Mercier's validated formula (Léger & Mercier, 1983).

Quantification of Exercise Training Load

HR and total time spent in each training intensity zone, and total exercise training load (TRIMP score) were recorded and quantified each single day of training during the two periods of 19 weeks in the two consecutive seasons. Total exercise training load was calculated multiplying the accumulated duration in each training zone by an intensity-weighted multiplier (e.g. 1 min in zone 1, 2 and 3 is multiplied by a score of 1, 2 and 3, respectively), according to Foster et al. (2001). Total TRIMP load was then obtained by computing the scores of the 3 zones.

Ratios of Perceived Exertion

After every training session the athlete recorded immediately his rating of perceived exertion (RPE) for the session utilizing the modified 10-point scale suggested by Foster et al. (2001).

Statistical Analyses

Statistical analysis was performed using *SPSS* software version 20 (IBM, Armonk, NY). The Kolmogorov-Smirnov test was applied to determine the normal distribution of the data. A paired *t*-test was used to compare the data between the two seasons. A Wilcoxon signed-rank test was applied as required. Cohen's *d* was also calculated for estimating the effect size (ES). Thresholds for effects were: "small" (*d*< 0.5), "medium" (*d*= 0.5-0.79) and "large" (*d*≥ 0.8).Statistical significance was set at P≤ 0.05.

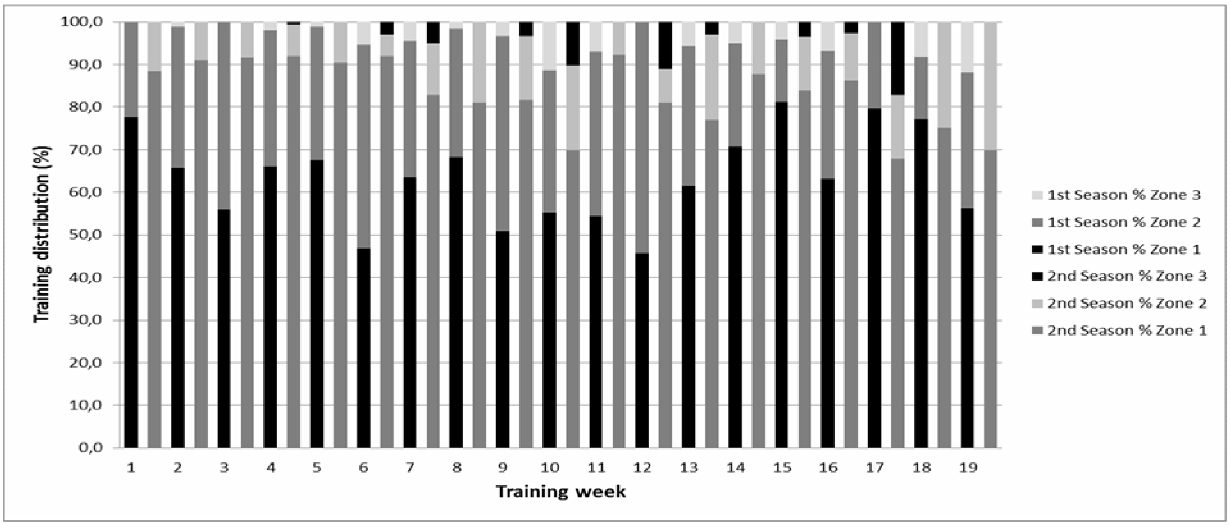
RESULTS

The athlete's characteristics derived from the physiological tests are shown in Table 1.

	1st Season	2nd Season	Δ (%)
AeT ($Mmol \cdot L^{-1}$)	2.5	2.4	-4
AnT ($Mmol \cdot L^{-1}$)	4.4	4.5	2.27
HR at AeT (bpm)	165	163	-1.21
HR at AnT (bpm)	177	175	-1.13
Speed at AeT ($km \cdot h^{-1}$)	14.0	14.0	0
Speed at AnT ($km \cdot h^{-1}$)	16.0	16.0	0
MAS ($km \cdot h^{-1}$)	17.0	18.0	5.88
Estimated VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	61.25	63	2.86

Table 1. Athlete's performance variables derived from the incremental tests in the 1st and 2nd season.
AeT: aerobic threshold; AnT: anaerobic threshold; HR: heart rate; MAS: maximum aerobic speed; VO_2max: maximum oxygen consumption; Δ: change from 1st to 2nd season expressed as percentage.

No significant differences were found for the average weekly training time between the two seasons (7 h 52 min ± 2 h 39 min *vs* 7 h 27min ± 2 h 05 min for the 1st and 2nd season, respectively; P> 0.05).
As it was expected, significant differences were found between the seasons for the time spent in the training zones 1 and 2 and the percentage of training time in those zones (see Table 2). Figure 1 shows the training intensity distribution over the microcycles of both seasons.
Figure 1. Training intensity distribution over the microcycles of the 1st and 2nd season.
Regarding the training load, the average weekly TRIMPs during the 1st season were significantly higher than those registered during the 2nd season (Table 2). Figure 2 shows the TRIMPs' evolution over the training

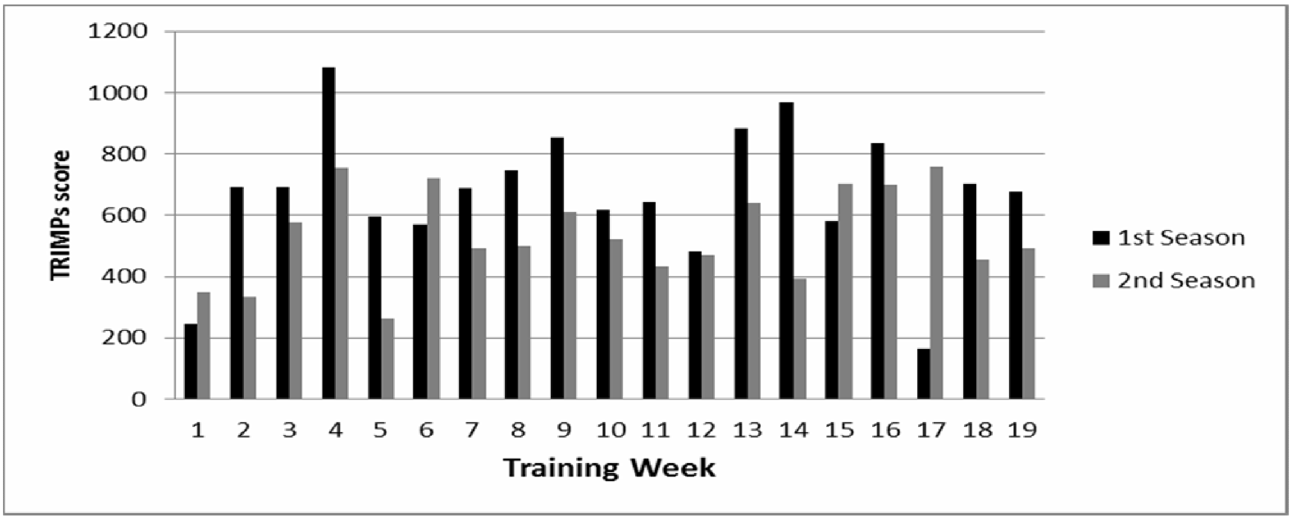


microcycles of each season.
No significant differences were found for RPE scores between the two seasons (P = 0.175) (see Table 2). However, when the RPE scores of the sessions -in which, at least, 50% of training time was spent in zone 2- were compared, the athlete's perception of effort changed from 5.1±1.4 to 8.8±0.8 for the 1st and 2nd season, respectively.
Table 2. Training characteristics and perception of effort in the 1st and 2nd season.

	1st Season (19th week)	2nd Season (19th week)	Δ (%)
Time (h:min:s)	1:26:34	1:20:22	-7.16
Maximum HR (bpm)	178	173	-2.81
Average HR (bpm)	167	164	-1.80
Average speed ($km \cdot h^{-1}$)	14.62	15.73	7.59
Average pace ($min \cdot km^{-1}$)	4:06	3:49	-6.91

HR: heart rate; Δ: change from 1st to 2nd season expressed as percentage.

Figure 2. TRIMPs score evolution over the training microcycles of the 1st and 2nd seaso



Finally, the athlete's half marathon performance was improved from the 1st to the 2nd season, decreasing his personal best in 7% (see Table 3).

Table 3. Performance evolution in half-marathon.

	1st Season	2nd Season	P Value	Cohen *d* (ES)
Average Time in Zone 1/wk(h:min)	5:01 (2:22)*	6:13 (2:01)	0.046	0.43
Average Time in Zone 2/wk (h:min)	2:32 (1:02)*	1:23 (0:27)	0.000	1.38
Average Time in Zone 3/wk(h:min)	0:14 (0:17)	0:24 (0:36)	0.376	0.22
Average % Training time zone 1/wk	63.5 (10.8)*	83.3 (8.1)	0.000	1.56
Average % Training time zone 2/wk	32.3 (10.6)*	13.6 (6.6)	0.000	1.63
Average % Training time zone 3/wk	4.2 (3.7)	3.2 (4.7)	0.484	0.2
Average TRIMPs/wk	670 (220)*	535 (149)	0.031	0.51
Average RPE/wk	5.6 (0.8)	5.4 (1)	0.175	-

Values are expressed as mean (SD). TRIMP: training impulse; RPE: ratio of perceived exertion. *Significant differences between 1st and 2nd seasons.

Discussion

The main finding of the present study was that a PTM reported a higher performance in a novice recreational endurance runner than a LTM approach. This study pointed out that although the training load was significantly higher during the 1st season (characterized by following a LTM), a PTM (during the 2nd season) significantly increased the athlete's half marathon performance with less training load but similar average training time. However, the major training load reported during the 1st season did not evidence significant differences for the RPE scores between the 1st and 2nd season.

It is well established that PTM shows a superior sport performance than LTM not only in elite (Ingham, et al., 2012; Laursen, 2010; Seiler, 2010; Seiler & Kjerland, 2006) but also in well-trained athletes (Esteve-Lanao, et al., 2005; Esteve-Lanao, et al., 2007; Garber et al. 2011; Muñoz, et al., 2014a; Muñoz, et al., 2014b; Neal, et al., 2013; Stöggl & Sperlich, 2014) who take part in endurance events. However, it was argued that novice athletes with little training experience could obtain more benefits following a LTM approach (Londeree, 1997), because they perceived the "easy" days of a PTM program as "too easy" and have not the ability to maintain a steady-state intensity (Winger, Murphy & Stavrianeas, 2009).

A previous 2 y-follow-up case study performed by Ingham et al. (2012) with a male international 1500-m runner evidenced a superior performance after a shift in training intensity distribution toward a PTM. In this interesting study, the authors showed that both low-intensity and "tempo" training were performed above the prescribed intensity. The difference between the prescribed and actual training intensity significantly decreased for low intensity training (i.e. <80% vVO2max) from 18% to 2.8%, while the Δ [blood lactate] for "tempo" training diminished from Δ6.7 mM to Δ2.5 mM in y 1 and 2, respectively (Ingham, et al., 2012). Similarly, our runner tended to train ~7% more time in zone 2 than that prescribed for the 1st season, which could be related to the lack of experience in the sports discipline for making a proper interpretation of the training goals (De

Andrade Nogueira, et al., 2015). In this regard, it is well established that training and competition experience plays a key role in sport performance (Kiviniemi, Hautala, Kinnunen, & Tulppo, 2007).

Our case report is in accordance with previous studies in the field with well-trained endurance runners. Esteve-Lanao et al. (2007) compared the effects of a LTM with a PTM approach over a 5-months training period. These authors demonstrated that a PTM program induces major improvements in many key physiological variables (e.g. running speed at AeT and AnT), achieving a better running performance of ~7% in cross-country races up to 10 km (Esteve-Lanao, et al., 2007). The training intensity distribution of our athlete is quite close to that reported by Esteve-Lanao et al. (2007). Total training time during the 1st session (i.e. LTM) was ~63%/32%/5% for zones 1/2/3, respectively, which is comparable to those values reported by Esteve-Lanao et al. (2007) for the LTM group (i.e. ~65%/25%/10%). On the other hand, during the 2nd season, our athlete followed a PTM program with a total training time of ~83%/14%/3% for zones 1/2/3, respectively, which is similar to the intensity distribution proposed by Esteve-Lanao et al. (2007) for the PTM group (i.e. ~80%/10%/10%), but far from those values reported by investigations with elite-endurance athletes (i.e. 75%/5%/20%) (Seiler, 2010). In this regard, our athlete would have to train more than 82 min per week in the intensity zone 3 to reach a "typically" elite-endurance athlete's polarized distribution. However, it seems to be quite difficult for a recreational runner with no much running experience to perform such amount of high intensity training. Further, some studies have demonstrated that total training time accumulated at low intensity (i.e. zone 1) is associated with a better endurance performance (Muñoz, et al., 2014a; Esteve-Lanao, et al., 2005). Based on our results, a less polarized training intensity distribution (e.g. ~85%/5%/10%) could be more appropriate for novice recreational runners, reporting not only performance but also fitness improvements.

Despite the fact that our runner showed no improvement in the variables related to the physiological thresholds (i.e. bpm, [La^+], and speed) derived from the incremental tests, both MAS and estimated VO_2max increased by 5.88% and 2.86%, respectively, after the PTM season. Furthermore, the 7% improvement in the half marathon performance experienced by our runner after the 2nd season is quite similar to those improvements showed by Esteve-Lanao et al.(2007) (7%) and, more recently, by Muñoz et al. (2014b) (5%) for 10 km running events after following a PTM program.

In relation to the training load, our athlete experienced a significant decrease for the TRIMP scores during the 2nd season, while total training time was not different between seasons. However, in our case report no meaningful differences were found for the average RPE scores between the two seasons. These results are in accordance with previous research that have demonstrated no relevant differences for RPE and sensations when LTM and PTM were compared, which suggests a good tolerance of training loads and similar adherence even in populations with little previous training background (Varela-Sanz, et al., 2017). A second analysis was performed to compare the RPE scores of the sessions in which at least the 50% of training time was spent in zone 2 (i.e. 23 sessions for the 1st season *vs* 5 sessions for 2nd season). The runner´s perception of effort for this zone changed from an average RPE score of 5.1±1.4 to 8.8±0.8 points for the 1st and 2nd season, respectively, which could be due to a worse habituation to these training intensity loads during the 2nd season (i.e. less weekly frequency).This data must be carefully interpreted due to the fact that training intensity zone 2 includes a wide range of intensities (i.e. the score for a minute at intensity close to AeT is the same as a minute at intensity of AnT). With the aim of avoiding these limitations and quantifying the training load more accurately, we recommend to divide the training intensity zones at least in five, as proposed by several studies (Cejuela & Esteve-Lanao, 2011; Mujika, et al., 1996; Seiler, 2010).

Our study presents several limitations. Firstly, we did not measure the heart rate variability (HRV) and therefore, we could not evaluate the ANS activity in both LTM and PTM seasons. Monitoring HRV might provide important information about the optimal athlete's physiological adaptation process, as recent studies have shown (Kiviniemi, et al., 2007; Vesterinen, et al., 2016). Based on previous studies in the field (Seiler, et al., 2007), it could be hypothesized that PTM caused fewer disturbances in ANS balance than LTM because of the large volume spent at low intensities (i.e. below AeT), avoiding the overreaching and overtraining syndromes, and therefore inducing better recovery strategies (Neal, et al., 2013). This assumptions and the fact that a PTM approach better mimics the physical activity pattern of our ancestors for survival (Boullosa, et al., 2013) might be the main underlying key factors for explaining the superiority of this model. Secondly, the VO_2max was not determined but estimated through a validated formula. In this regard, it was previously suggested that an increase in MAS is related to an improvement of VO_2max (Varela-Sanz, et al., 2017). Thirdly, the runner's diet patterns were not controlled. Finally, this investigation is a case report and therefore, our results should be only extrapolated to similar populations.

In summary, our results suggest the appropriateness of applying a PTM program in endurance runners with little running training experience, but moderate weekly training frequency. The main finding of the present study was that a shift in training from a LTM approach to a PTM with similar average weekly training time, leads to an improvement of 7% in half marathon performance, even with a significant lower training load. Further studies are needed to ascertain if recreational endurance athletes with little training background could experience greater long-term benefits when they train in a more polarized fashion than in the present study (i.e. accumulating more training time in zone 3).

Conclusions

When training time (i.e. volume) and training sessions (i.e. frequency) are limited by the availability of time, the intensity and its distribution raises as the key factor to promote a higher performance in endurance athletes. PTM might be the best model to improve athletic performance whether the athlete spends a large amount of time at training. Nevertheless, future studies are needed to confirm this hypothesis, especially when athletes have little training background in the studied endurance-sports modality.

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