# Polarized and pyramidal training intensity distributions in distance running: an integrative literature review

Bence Kelemen [a*], Otto Benczenleitner [b], Laszlo Toth [c, d]

[a]*School of Doctoral Studies, Hungarian University of Sport Science, Budapest*

[b]*Károly Eszterházy Catholic University, Institute of Sports Science*

[c]*Department of Psychology and Sport Psychology, Hungarian University of Sport Science, Budapest*

[d]*Teacher Training Institute, Hungarian University of Sports Science, Budapest*

bencekelemen95@gmail.com

**Absztrakt:**

A tanulmány célja, hogy megvizsgálja a különbségeket és hasonlóságokat a szakirodalomban a nemzetközi elit távfutók (1500-10.000 m) legjellemzőbb edzésmódszereként leírt polarizált és piramis-intenzitású edzésmódszerek között. Anyag és módszerek: Az internetes adatbázisok áttekintése után 26 szakirodalmi cikket találtunk, amelyek a nemzetközi távfutók edzésintenzitás-eloszlását elemzik. Eredmények: Mindkét edzésmódszerben az elit távfutók átlagosan heti 120-180 km-t tesznek meg, amelynek 75-80%-át alacsony intenzitással, az aerob küszöbérték (vLT1) alatt teljesítik. A piramis módszerben a futók átlagosan heti 2-4 alkalommal végeznek intervallumos vagy folyamatos tempó futás edzéseket az anaerob küszöb alatti sebességgel (vLT2). Ezzel szemben a polarizált intenzitás eloszlásban átlagosan heti 1 alkalommal végeznek intervallokat az anaerob küszöb felett a futók a vVo2max 90%-ánál. Mindkét edzésmódszerben versenytempóhoz közeli sebességet rövid intervallumok (< 800 m) formájában végeznek edzéseket az alapozó időszakban. Következtetések: A modern távfutók edzését az aerob kapacitás hangsúlyos fejlesztése jellemzi, amelyet elsősorban nagy mennyiségű, alacsony intenzitású munkával és heti 1-4 anaerob küszöb edzéssel érnek el. A sportolók rövid intervallumokat és rövid sprinteket alkalmaznak az anaerob képességek és a versenysebességhez kapcsolatos koordináció szintentartása érdekében. A versenyeket megelőző formábahozó időszakban kezdik el a hosszabb, intenzív versenyspecifikus intervall edzések alkalmazását. A versenyszezonban a futók az állóképességet jelentős mennyiségű alacsony intenzitású futással és kevésbé hangsúlyos anaerob küszöb edzéssel tartják fent.

**Kulcsszavak:** polarizált edzés, piramis edzés, intenzitás eloszlás, távfutás

**Abstract:**

This study aims to investigate the differences and similarities between the polarized and pyramid-intensity training methods described in the literature as the most typical training methods for elite international distance runners (1500- 10,000 m). Material and Methods: 26 literature articles analyzing the training intensity distribution of international distance runners were found after a review of internet databases. Results: In both training methods, elite track runners cover an average of 120-180 km per week, 75-80% of which is done at low intensity, below the aerobic threshold (vLT1). In the pyramid method, runners perform interval or continuous tempo running workouts at speeds below the anaerobic threshold (vLT2) on average 2-4 times per week. In contrast, in the polarized intensity distribution, interval training is performed on average 1 time per week above the anaerobic threshold at 90% of vVo2max. Intensities near race speed are performed as short intervals (< 800m) during the base period. Conclusions: The training of modern distance runners is characterized by an emphasis on the development of aerobic capacity, achieved primarily through high amounts of low-intensity work and 1-4 anaerobic threshold training sessions per week. Athletes use short intervals and short sprints to maintain their anaerobic abilities and their coordination at race speed. They start using longer, intensive race-specific work in the period leading up to races. During the racing season, runners maintain endurance with a significant amount of low-intensity running and less pronounced anaerobic threshold training.

**Keywords:** polarized training, pyramid training, intensity distribution, distance running

**Introduction:**

Over the past decades, there have been numerous publications in the international literature on the physiological, anthropometric, and morphological factors that are essential for successful performance in middle and long-distance running (*Kovács, Kóbor, Sebestyén and Tihanyi*, 2021). In terms of physiological factors, these are maximal oxygen uptake (VO2max), running economy (RE), and velocity associated with maximal oxygen uptake (vVo2max) (*Noakes Myburgh and Schall*, 1990; *Noakes*, 2001, *Conley and Krahenbuhl*, 1980). In addition to these factors, the anaerobic threshold and associated running speed (vAt) are the best predictors of distance running performance (*Tjelta, Tjelta and Drystad*, 2012). Since the beginning of the last century, training methods to improve these abilities have been continuously improved based on empirical observations by coaches. A consensus has emerged among coaches and researchers that interaction between three main factors plays a role in the development of these parameters: training volume (number of kilometers over a given period), training density, and training intensity (*Foster, Daniels and Seiler*, 1999; *Midgley, McNaughton and Jones,* 2007; *Brandon*, 1995). However, these combinations may vary from one event to another, from one athlete to another (*Seiler and Tonessen*, 2009). There may also be variations in the training tool that coaches use to achieve a given physiological adaptation. The literature uses different intensity-zone-based schemes to classify the training performed by endurance athletes (*Seiler and Kjerland*, 2006). The most widely used is the 3-zone scale associated with the name Stephen Seiler (see Table 1.) (*Seiler*, 2010). Here, work below the aerobic threshold (vLT1) is classified as Low-Intensity Training (LIT), between the aerobic and anaerobic thresholds (vLT1 and vLT2) as Moderate Intensity Training (MIT), and above the anaerobic threshold as High-Intensity Training (HIT). In addition to the above-mentioned scales, 5-zone (*Tjelta*, 2016) and 9-zone scales (*Haugen, Sandbakk, Enoksen, Seiler and Tonessen,* 2021) for middle-distance runners are also used. These are mainly based on physiological parameters (aerobic and anaerobic threshold) (*Seiler*, 2010), but some researchers also suggest the use of pace relative to race pace (*Kenneally, Casado, Gomez-Ezeiza and Santos Concejero*, 2020; *Kelemen, Benczenleitner and Tóth*, 2023a). The training intensity distribution (TID) is the most commonly distinguished training method used in research:

- **Traditional/ Pyramidal distribution:** most of the training volume (around 70-80%) is done at low intensity (Zone 1). The remaining 20-30% is at medium to high intensity, such that there is more medium intensity (Zone 2/ Anaerobic threshold training) and less of the highest intensity (Zone 3). As the workloads get higher, the amount of work done by the runner decreases, so, a pyramid is drawn.
- **Polarized training:** in the method described by Stephen Seiler (*Seiler and Kjerland*, 2004), athletes perform large amounts of low-intensity (Zone 1 ~ 80%) and high-intensity (Zone 3 ~ 20%) work, while very little or no effort is performed at moderate intensity (Zone 2). A Polarization Index (PI): PI=$\log_{10}$ (Z1/Z2 x Z3*100) calculus was created by Treff and his co-workers to determine whether the training intensity distribution counts as Polarized, where Polarized if PI > 2.00 a.U. (*Treff, Winkert, Sareban, Steinacker and Sperlich*, 2019).
- **Anaerobic threshold training/ Threshold training:** in contrast to the other two methods, the majority of training (>35%) takes place in Zone 2, which is associated with the anaerobic threshold, but here too the majority of work (60-62%) is performed at low intensity (Zone 1). However, this latter method is not typical of the ascent of professional international distance runners, according to the work of Casado et al. (*Casado, González-Mohíno, González-Ravé and Foster*, 2022).

As the running distances between 1500 m and 10,000 m are dominated by aerobic energy expenditure (*Gastin*, 2001), their training shows a homogeneous picture. However, the preparation of 800 m athletes, differs from these longer events (*Haugen et al.,* 2021). For the shorter distance of 1500 m, 75-80% of the energy is derived from aerobic energy, while for the 10 km, 95% is derived from aerobic energy. The races' energy production differences are also reflected in their pacing (*Tucker, Lambert and Noakes,* 2006; *Kelemen, Csányi, Révész, Gyimes, Benczenleitner and Tóth*, 2023b; *Filipas, Nerli, Bonato, La Torre and Piacentini*, 2018).

| Stephen Seiler's 3-intensity zone scale | | | | | |
|---|---|---|---|---|---|
| Zone | Intensity | Lactate (mmol/liter) | VO2max % | HR max % | Training type |
| **Zone 3** | High Intensity (HIT) | >4.0 | >90% | 92-100% | Aerobic power; Anaerobic intervals; Speed development |
| **Zone 2** | Moderate Intensity (MIT) | 2.0-4.0 | 80-89% | 82-92% | Lactate threshold training |
| **Zone 1** | Low intensity (LIT) | 1.0-2.0 | 55-79% | 62-82% | Aerobic endurance; Aerobic recovery |

**Table 1. The Stephen Seiler 3- intensity zone scale (*Seiler*, 2009).**

Several studies have been published on different intensity-based approaches. Some of these were short-term and focused on local, amateur-level athletes *(Filipas, Bonato, Gallo and Godella, 2022)*. In the literature on the training of elite athletes, examples of both polarised and pyramidal distributions can be found, so different approaches appear to be used to achieve similar levels of results in distance runners *(Kenneally, Casado, Gomez-Ezeiza and Santos Concejero, 2020; Tjelta, 2013; Tjelta, 2016; Ingham, Fudge and Pringle, 2012; Seiler, 2010)*. In the present study, we have sought to explain the phenomenon of how it is possible to achieve similar results with seemingly two different approaches, and what are the key training elements that enable this high level of endurance performance. Finally, how these observations can be put to use in practical preparation.

**Aim:**

The literature on the subject shows that at the highest level, the training of elite international distance runners (1500-10,000m) is mainly characterised by Polarised and Pyramidal intensity distribution methods *(Foster, Casado, Esteve-Lanao, Haugen and Seiler, 2022; Casado et al., 2022)*. For this reason, the aim of this study is to investigate the differences and similarities between these two methods. The study investigated the following aspects: training volume, intensity distribution, training tools and periodization. A further aim of the research is to draw conclusions from the training of elite athletes that can be used by coaches in their practical work.

**Material and Methods:**

An integrative review was conducted to evaluate training intensity studies in elite-level distance running. An integrative review is a broad research review that allows the researcher to combine theoretical and empirical literature and includes different types of data and different methods (*Whittemore and Knafl*, 2005). The present review followed the process described by Whittemore and Knafl (2005), which includes problem identification, literature search, data evaluation, data analysis, and presentation of results. A literature search was conducted on Feb 20, 2023. After a review of the following internet databases (Pubmed, Scopus, Web of Science), 26 literature articles were found analyzing the training intensity distribution (TID) of international distance runners. Databases were searched from inception up to February 2023, with no language limitation. Citations from scientific conferences were excluded. The title, abstract, and keywords search fields were searched in each database. The following keywords, combined with Boolean operators (AND, OR) were used: „Training", „Running", „Long-distance", „Polarised", „Pyramidal", „Intensity", and „Intensity distribution". The types of articles analyzed were review articles, original research, case studies.

**Results:**

**Similarities:**

In terms of the amount of training per week, both methods are similar. Elite 1500 and 10,000-meter runners average between 120 and 180 kilometers per week, with 10 to 14 running sessions weekly (*Haugen, Sandbakk, Seiler and Tonessen,* 2022; *Casado et al.,* 2022; *Karikosk*, 1984; *Tjelta*, 2016; *Tjelta and Enoksen*, 2001). A significant part of the training volume is done at low intensity **(see Figure 1.)**, both in the pyramidal and polarised models. Runners complete 75-80% of their weekly mileage at low intensity (Zone 1), below the aerobic threshold (vLT1), which in their case is roughly the pace of their estimated marathon race pace (*Kenneally et al.,* 2017; *Enoksen, Tjelta and Tjelta*, 2011). The most commonly used forms of exercise in this category are 30-70 minute aerobic maintenance runs and shorter warm-up and cool-down runs, and morning shake-outs. Most elite runners do a long run once a week for 90-120 minutes, at the end of which the intensity can reach Zone 2 (*Seiler*, 2010; *Stöggl*, 2015, *Esteve-Lanao, San Juan, Earnest, Foster and Lucia,* 2005). The highest intensities, close to race pace, are performed at short intervals (< 800 m) 1-2 times per week in both training regimes during the base period, with lactate levels below 8 to 10 mmols/l (*Casado, Hanely, Santos-Concejero and Ruiz-Pérez,* 2021). These short interval workouts are done either on hills or on flat terrain (track). The duration of the intervals is usually 0.5-1 minute and they are often done in sets (for example 2x10x200 meter hills), usually running about 4-8 kilometers of intense distance per session. In the 4-8 weeks before the race season the use of longer, race-specific intervals with high lactic acid levels (> 8 mmol/l) is started to mimic the fatigue the runners will face on the race day (*Casado et al.,* 2021; *Haugen et al.,* 2022).
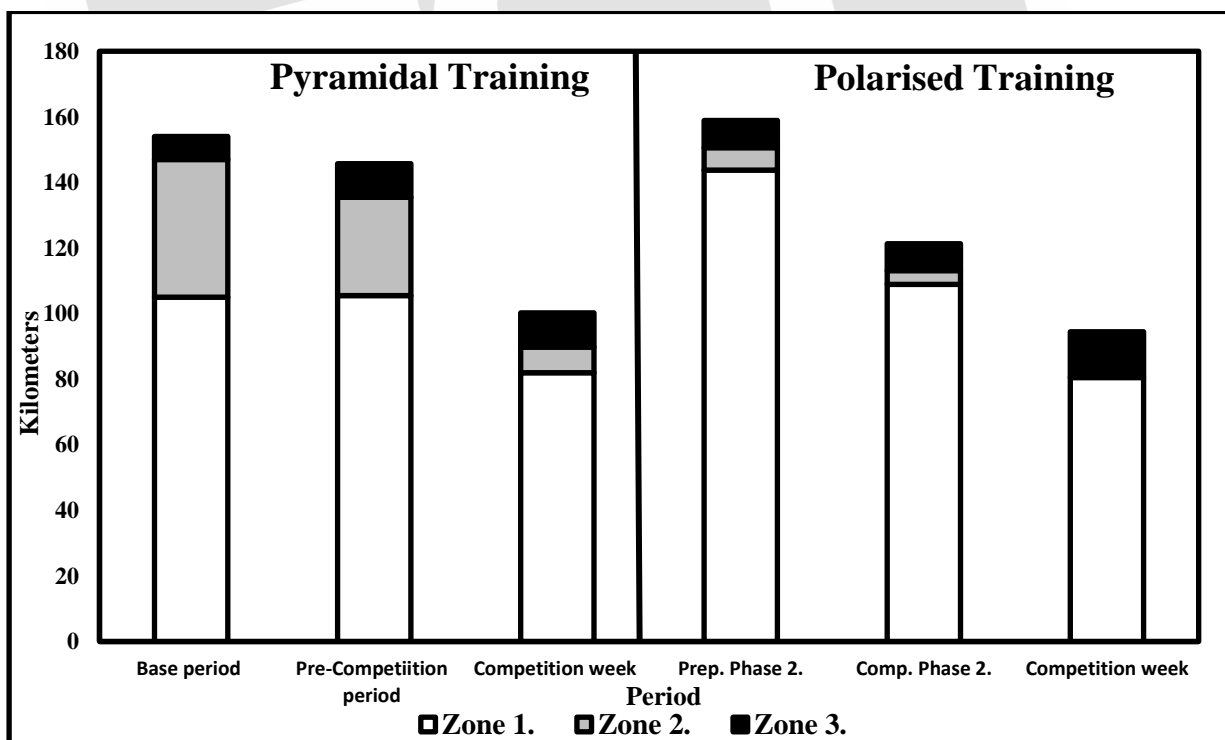


**Figure 1. Training volume and training intensity distribution data for different periods of season in the Pyramid and Polarized training methods (*Kelemen et al.,* 2023a; *Tjelta*, 2013).**

**Differences:**

The biggest difference between the two methods was found in high-intensity aerobic work **(See Table 2)**. In the pyramid method, runners performed interval or continuous tempo running workouts at speeds below the anaerobic threshold (vLT2) on average 2-4 times per week (*Tjelta, Tonessen, and Enoksen*, 2014). More recently, the use of interval training controlled by lactate measurement has become more common (*Casado, Foster, Bakken, and Tjelta*, 2023). The specification of the Norwegian method, which has been very well published in the literature, is that twice a week, so-called double-threshold days are performed, whereby runners run 20 km worth of intervals below the anaerobic threshold during the day **(see Table 2)**. In the

mornings, they mainly run longer 6-10 minutes marathon-paced intervals with short breaks, while in the afternoon they run shorter, faster (5km to half-marathon paces) part-distances between 1000m and 400m. Because of the short rest periods and the interval format, they can run faster than the laboratory threshold speed without exceeding a blood lactate level of 4 mmol/l. (*Bakken*, 2021; *Tjelta*, 2013; *Tjetla*, 2016; *Tjelta*, 2019). In contrast, in the polarised intensity distribution, interval training was performed on average 1 time per week above the anaerobic threshold (vLT2) at 90% of vVo2max, which for elite racers is approximately 10 km or 30-minute race pace. Typically, 30-40 minutes of intensive work is done in 3-10 minute intervals (1-3 km distances) with a rest-to-run ratio of about 1:3 or 1:2. Light jogging or walking is typical during the rest periods. A common example of this type of training is the 5-6x mile (1609 meters) or 8x1000 meters workout (*Keneally, Casado, Gomez-Ezeiza and Santos-Concejero*, 2022; *Ingham, Fudge and Pringle*, 2012; *Billat, Lepretre, Heugas, Salim, and Koralsztein*, 2003), or the 8x4 minutes with 2-minute rest recommended by Stephen Seiler, up to 4x8 min with 4 min rest at 90% of vVo2max, or 90-93 % mHR (*Filipas, Bonato, Gallo and Godella*, 2022; *Seiler, Joranson, Olesen and Hetleid*, 2013). These training sessions can also take a more typical directional-fartlek form at the beginning of the build-up period, where the intense part is given in time and not distance. Common examples of these fartlek-sessions are 8-10 x 3 minutes hard (so-called „on") with 1.5-2 minutes rest („off"), or pyramidal/ ladder sets like 1-2-3-4-5-4-3-2-1 minute intense runs with the same time of easy running in between hard efforts. In addition to the isolated use of these two methods, there are many examples of athletes' training following a pyramidal distribution in the base period and then a polarised pattern as the race period approaches (*Kenneally et al.,* 2022).

**Discussion:**

The training of modern distance runners is characterized by a strong emphasis on developing aerobic capacity, primarily through high volume, low intensity running and increasingly interval training 1-4 times per week to develop anaerobic threshold speed. The Pyramid Method is characterized by 2-4 anaerobic threshold (vLT2) tempo/interval training sessions per week. The Polarised Method is characterized by 1 interval training session per week above the anaerobic threshold (90% vVo2max), with 30-40 minutes of intense work. Short (< 800 m) intervals close to the race pace and short sprints are used to maintain anaerobic capacity and race pace coordination during the build-up. In the pre-competition period (4-8 weeks), longer, intensive, competition-specific interval training sessions begin. During the racing season, they maintain the endurance gained in the pre-season, continuing with a significant amount of low-intensity running and less pronounced but present anaerobic threshold training. Monitoring intensity (heart rate, blood lactate, pace charts) and using appropriate intensity zones (e.g. recovery runs/anaerobic threshold runs) is essential to perform high-volume work and prevent overload. During the season, linear periodization is typical in both cases, with the possibility of single or double form timing (one during the winter indoor season and one during the summer competitive season). In both intensity models, the PI (Polarization Index) increases during the season, which is due to the use of more intense training sessions that simulate near-race fatigue as the race approaches, increases, and in parallel the importance of endurance training (zone 2) is pushed back. Apart from using the two intensity models separately, there are several examples in the literature where the intensity distribution of the competitors has shown a pyramidal pattern in the baseline period and then becomes polarised in the pre-race formative period for the reasons mentioned above (increase in PI). In both cases, an alternation of light and heavy workload days (both in terms of volume and training intensity) can be observed within the micro-cycles of the weekly training schedule. Most runners have 5-10 years of systematic high-volume training before they reach the international level. Those runners who have developed their aerobic skills in their early years, with high volumes of low-intensity runs and frequent high-aerobic training, will achieve greater success in the long term and sustain their best years for longer periods (*Casado, Hanley and Luiz-Pérez*, 2020; *Tjelta*, 2010).

**Table 2. Training week examples in the Pyramidal and Polarized training method during the base season. (*Kelemen et al.*, 2023a; *Bengtsson*, 2019).**

| Day | Polarized Training | Pyramidal Training |
|---|---|---|
| **Monday** | AM: 16.13 km, average pace 4:06 min/km (Zone 1) | AM 10 km easy (Zone 1) <br> PM 10 km easy, speed development (Zone 1) |
| **Tuesday** | AM: 29.02 km, average pace 3:43 min/km (Zone 1) | **AM Anaerobic threshold workout: 5 x 6 minutes (1 min rest), 2.5 mmol/L (Zone 2)** <br> **PM Anaerobic threshold workout: 10 x1000 m (1 min rest), 3.5 mmol/L (Zone 2)** |
| **Wednesday** | AM: 16.13 km, average pace 3:52 min/km (Zone 1) <br> PM: 8.04 km, average pace 4:00 min/km (Zone 1) +drills | 10 km easy, strength and core (Zone 1) |
| **Thursday** | AM: 8.08 km, average pace 3:54 min=km (Zone 1) <br> PM: 4.8 km warm-up (Zone 1) <br> **3x4x200m with 200 m and 400 m jog recovery (28, 27, 26-sec average)** <br> **8x200m hills (33-31 sec)** (Zone 3) <br> 5 km warm-down (Zone 1) | **AM Anaerobic threshold workout: 5 x 2 km (1 min rest), 2.5 mmol/L (Zone 2)** <br> **PM Anaerobic threshold workout: 25 x 400 m (30-sec rest), 3.5 mmol/L (Zone 2)** |
| **Friday** | AM: 14.52 km, average pace 3:59 min/km (Zone 1) + weight training | 10 km easy (Zone 1) |
| **Saturday** | AM: 16.13 km, average pace 4:04 min/km (Zone 1) | **AM Hill training: 20 x 219-meter hills (70-sec jog back), 8,0 mmol/L (Zone 3)** <br> PM 10 km easy (Zone 1) |
| **Sunday** | AM: 8.07 km, average pace 3:56 min/km (Zone 1) <br> PM: 4.8 km warm-up (Zone 1) <br> **4x (2km-1km) with 2 and 3 min recovery (5:50; 2:42; 5:50; 2:42; 5:50; 2:41; 5:50; 2:40)** (Zone 2-3) <br> 4 km warm-down (Zone 1) <br> *Weekly total: 166.1 km* <br> *(Z1: 89,7%, Z2: 4,81 %, Z3: 5,41 %)* | AM 20 km long run (Zone 1) <br> PM Strenght and core <br> *Weekly total: 140 km* <br> *(Z1: 70%; Z2 26%; Z3 4%)* |

* Workouts done at higher intensities ( Zone 2 and Zone 3) are highlighted with bold text.

**Conclusions and Practical Applications:**

The integrative literature review resulted in the following key findings: the two internality zone models that best characterize the training of elite distance runners are largely identical. The main differences lie in the number and use of high-intensity aerobic training sessions. Whereas in the polarised method, the anaerobic threshold is "pulled up" by a high volume of high intensity (30-40 minutes of intensive training) once a week at a slightly higher intensity than the anaerobic threshold (vLT2). In the pyramidal distribution, the same speed is „pushed up" by more frequent (2-4) intervals or tempo training below the anaerobic threshold (between aerobic/ vLT1 and anaerobic/ vLT2 thresholds). The observations that have been successfully used in both methods and that can be put into practice by coaches are summarised below:

- To achieve an international level of distance running performance, a high level of weekly training (120-180 km/week) is required.
- Most runners have 5-10 years of systematic training of high quality and quantity before achieving an outstanding result.
- A high percentage of the weekly training (70-80%) should be low intensity, below the aerobic threshold (marathon pace).
- During the base period, focus on developing speed at the anaerobic threshold (vLT2) with high-intensity aerobic tempo or interval training 1-4 times per week, using paces between Marathon and 10 km race speeds, with 20-40 minutes worth of intensive work per session.
- Maintain race speed-related coordination and anaerobic capacity with short interval running (>800 m) on flat or uphill terrain, on average 1 time per week, with controlled lactate accumulation (>8 mmol/L) during the base period.
- Development and maintenance of maximal running speed using short sub-maximal sprint runs with full rest (> 15 seconds) and using conditioning and plyometric exercises.
- Use of longer race-specific anaerobic (< 8 mmol/l) intervals 1-2 times per week in a 4-8 week pre-competition period, before racing season.
- Maintain the endurance level acquired during the race period with high volumes of low-intensity running and level-maintaining anaerobic threshold training.
- To avoid overtraining, close monitoring of intensity zones and training paces, especially during low-intensity (Zone 1) and near anaerobic threshold (Zone 2) training, using heart rate monitoring, pace charts, and lactate measurement.

**References:**

1. Bakken M. The Norwegian model. http://www.mariusbakken.com/the-norwegian-model.html (2021, acessed 25 January 2022)
2. Bence Kelemen, Tamas Csanyi, Laszlo Revesz, Zsolt Gyimes, Otto Benczenleitner, Laszlo Toth (2023b): Comparison of Winning and Record Tactics in Elite-Level Male Middle-Distance Running; Journal of Physical Education and Sport ® (JPES), Vol. 23 (issue 2), Art 58, pp. 469 - 475, February 2023 online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES; DOI:10.7752/jpes.2023.02058
3. Bengtsson J. Kalle Berlgrund training program. https://pajulahti.com/wp-content/uploads/2020/01/Jan-Bengtsson-Pajulahti.pdf (2019, accessed 25 January 2022)
4. Billat VL, Lepretre PM, Heugas AM, Laurence MH, Salim D, Koralsztein JP. Training and bioenergetic characteristics in elite male and female Kenyan runners. Med Sci Sports Exerc. 2003;35(2): 297–304. PubMed ID: 12569219 doi:10.1249/01.MSS.0000053556. 59992.A9
5. Brandon L. J. (1995). Physiological factors associated with middle distance running performance. *Sports medicine (Auckland, N.Z.)*, *19*(4), 268–277. https://doi.org/10.2165/00007256-199519040-00004
6. Casado, A., Foster, C., Bakken, M., & Tjelta, L. I. (2023). Does Lactate-Guided Threshold Interval Training within a High-Volume Low-Intensity Approach Represent the "Next Step" in the Evolution of Distance Running Training? *International Journal of Environmental Research and Public Health*, *20*(5), 3782. MDPI AG. Retrieved from http://dx.doi.org/10.3390/ijerph20053782
7. Casado, A., González-Mohíno, F., González-Ravé, J. M., & Foster, C. (2022). Training Periodization, Methods, Intensity Distribution, and Volume in Highly Trained and Elite Distance Runners: A Systematic Review. *International Journal of Sports Physiology and Performance*, *17*(6), 820–833. https://doi.org/10.1123/ijspp.2021-0435
8. Casado, A., Hanley, B., & Ruiz-Pérez, L. M. (2020). Deliberate practice in training differentiates the best Kenyan and Spanish long-distance runners. *European journal of sport science*, *20*(7), 887–895. https://doi.org/10.1080/17461391.2019.1694077
9. Casado, A., Hanley, B., Santos-Concejero, J., & Ruiz-Pérez, L. M. (2021a). World-Class Long-Distance Running Performances Are Best Predicted by Volume of Easy Runs and Deliberate Practice of Short-Interval and Tempo Runs. *Journal of Strength and Conditioning Research*, *35*(9), 2525–2531. https://doi.org/10.1519/jsc.0000000000003176

10. Conley DL and Krahenbuhl GS. Running economy and distance running performance of highly trained athletes. Med Sci Sports Exerc 1980; 12: 357–360.

11. Enoksen, E., Tjelta, A.R., & Tjelta, L.I. (2011). Distribution of Training Volume and Intensity of Elite Male and Female Track and Marathon Runners. *International Journal of Sports Science & Coaching, 6*, 273 - 293.

12. Esteve-Lanao, J., San Juan, A. F., Earnest, C. P., Foster, C., & Lucia, A. (2005). How do endurance runners actually train? Relationship with competition performance. *Medicine and science in sports and exercise*, *37*(3), 496–504. https://doi.org/10.1249/01.mss.0000155393.78744.86

13. Filipas L, Bonato M, Gallo G, Codella R. Effects of 16 weeks of pyramidal and polarized training intensity distributions in well-trained endurance runners. Scand J Med Sci Sports. 2021;32(3): 498–511. PubMed ID: 34792817 doi:10.1111/sms.14101

14. Filipas, L., Nerli Ballati, E., Bonato, M., La Torre, A., & Piacentini, M. F. (2018). Elite Male and Female 800-m Runners' Display of Different Pacing Strategies During Season-Best Performances, *International Journal of Sports Physiology and Performance*, *13*(10), 1344-1348. Retrieved Apr 17, 2023, from https://doi.org/10.1123/ijspp.2018-0137

15. Foster, C., Casado, A., Esteve-Lanao, J., Haugen, T., & Seiler, S. (2022). Polarized Training Is Optimal for Endurance Athletes. *Medicine and science in sports and exercise*, *54*(6), 1028–1031. https://doi.org/10.1249/MSS.0000000000002871

16. Foster, C.C., Daniels, J.T., & Seiler, S. (1999). Perspectives on Correct Approaches to Training.

17. Gastin P. B. (2001). Energy system interaction and relative contribution during maximal exercise. *Sports medicine (Auckland, N.Z.)*, *31*(10), 725–741. https://doi.org/10.2165/00007256-200131100-00003

18. Haugen T, Sandbakk Ø, Seiler S, Tønnessen E. The Training Characteristics of World-Class Distance Runners: An Integration of Scientific Literature and Results-Proven Practice. Sports Med Open. 2022 Apr 1;8(1):46. doi: 10.1186/s40798-022-00438-7. PMID: 35362850; PMCID: PMC8975965.

19. Haugen, T., Sandbakk, Ø., Enoksen, E., Seiler, S., & Tønnessen, E. (2021). Crossing the Golden Training Divide: The Science and Practice of Training World-Class 800- and 1500-m Runners. *Sports medicine (Auckland, N.Z.)*, *51*(9), 1835–1854. https://doi.org/10.1007/s40279-021-01481-2

20. Ingham, S. A., Fudge, B. W., & Pringle, J. S. (2012). Training Distribution, Physiological Profile, and Performance for a Male International 1500-m Runner. *International Journal of Sports Physiology and Performance*, *7*(2), 193–195. https://doi.org/10.1123/ijspp.7.2.193

21. Karikosk O., Training Volume in Distance Running, *Modern Athlete and Coach*, 1984, 22(2), 18–20.

22. Kelemen Bence, Benczenleitner Ottó, Tóth László (2023a): Polarized training intensity distribution in distance running: a case study of the 2021 Olympic long-distance runner (under review: German Journal of Exercise and Sport Research)

23. Kenneally, M., Casado, A., & Santos-Concejero, J. (2017). The Effect of Periodization and Training Intensity Distribution on Middle- and Long-Distance Running Performance: A Systematic Review. *International journal of sports physiology and performance, 13 9*, 1114-1121 .

24. Kenneally, M., Casado, A., Gomez-Ezeiza, J., & Santos-Concejero, J. (2020). Training intensity distribution analysis by race pace vs. physiological approach in world-class middle- and long-distance runners. *European Journal of Sport Science*, *21*(6), 819–826. https://doi.org/10.1080/17461391.2020.1773934

25. Kenneally, M., Casado, A., Gomez-Ezeiza, J., & Santos-Concejero, J. (2022). Training Characteristics of a World Championship 5000-m Finalist and Multiple Continental Record Holder Over the Year Leading to a World Championship Final. *International Journal of Sports Physiology and Performance*, *17*(1), 142–146. https://doi.org/10.1123/ijspp.2021-0114

26. Kovács, B., Kóbor, I., Sebestyén, Ö., & Tihanyi, J. (2021). Longer Achilles tendon moment arm results in better running economy. *Physiology international*, *107*(4), 527–541. https://doi.org/10.1556/2060.2020.10000

27. Leif Inge Tjelta. (2013). A Longitudinal Case Study of the Training of the 2012 European 1500m Track Champion. *IJASS(International Journal of Applied Sports Sciences)*, *25*(1), 11–18. https://doi.org/10.24985/ijass.2013.25.1.11

28. Midgley, A. W., McNaughton, L. R., & Jones, A. M. (2007). Training to enhance the physiological determinants of long-distance running performance: can valid recommendations be given to runners and coaches based on current scientific knowledge?. *Sports medicine (Auckland, N.Z.)*, *37*(10), 857–880

29. Noakes T. Physiological capacity of the elite runner. In: Bangsbo J and Larsen HB (eds) Running and science: an interdisciplinary perspective. Copenhagen: Institute of Exercise and Sports Sciences, University of Copenhagen, Munksgaard, 2001, pp.19–47

30. Noakes, T. D., Myburgh, K. H., & Schall, R. (1990). Peak treadmill running velocity during the VO2 max test predicts running performance. *Journal of sports sciences*, *8*(1), 35–45. https://doi.org/10.1080/02640419008732129

31. Seiler, K. S., & Kjerland, G. Ø. (2006). Quantifying training intensity distribution in elite endurance athletes: is there evidence for an "optimal" distribution?. *Scandinavian journal of medicine & science in sports*, *16*(1), 49–56. https://doi.org/10.1111/j.1600-0838.2004.00418.x

32. Seiler, S. (2010). What is Best Practice for Training Intensity and Duration Distribution in Endurance Athletes? *International Journal of Sports Physiology and Performance*, *5*(3), 276–291. https://doi.org/10.1123/ijspp.5.3.276

33. Seiler, S., & Tønnessen, E. (2009). Intervals, Thresholds, and Long Slow Distance: the Role of Intensity and Duration in Endurance Training.

34. Seiler, S., Jøranson, K., Olesen, B. V., & Hetlelid, K. J. (2013). Adaptations to aerobic interval training: interactive effects of exercise intensity and total work duration. *Scandinavian journal of medicine & science in sports*, *23*(1), 74–83. https://doi.org/10.1111/j.1600-0838.2011.01351.x

35. Stöggl, T. L., & Sperlich, B. (2015). The training intensity distribution among well-trained and elite endurance athletes. *Frontiers in Physiology*, *6*. https://doi.org/10.3389/fphys.2015.00295

36. Tjelta, L. I. (2016). The training of international level distance runners. International Journal of Sports Science & Coaching, 11(1), 122–134. https://doi.org/10.1177/1747954115624813

37. Tjelta, L. I. (2019). Three Norwegian brothers all European 1500 m champions: What is the secret? International Journal of Sports Science & Coaching, 14(5), 694–700. https://doi.org/10.1177/1747954119872321

38. Tjelta, L. I., & Enoksen, E. (2010). Training Characteristics of Male Junior Cross Country and Track Runners on European Top Level. International Journal of Sports Science & Coaching, 5(2), 193–203. https://doi.org/10.1260/1747-9541.5.2.193

39. Tjelta, L. I., Tønnessen, E., & Enoksen, E. (2014). A Case Study of the Training of Nine Times New York Marathon Winner Grete Waitz. International Journal of Sports Science & Coaching, 9(1), 139–158. https://doi.org/10.1260/1747-9541.9.1.139

40. Tjelta, L.I. (2013). A Longitudinal Case Study of the Training of the 2012 European 1500m Track Champion. *International Journal of Applied Sports Sciences, 25*, 11-18.

41. Tjelta, L.I., Enoksen, E. (2001) Training volume and intensity. *Running and Science- in an Interdisiplinary Perspective*, 2001, 149-177., Publisher: University of Copenhagen

42. Tjelta, Leif Inge & Rønning Tjelta, Asle & Dyrstad, Sindre. (2012). Relationship between Velocity at Anaerobic Threshold and Factors Affacting Velocity at Anaerobic Threshold in Elite Distance Runners. International Journal of Applied Sports Sciences. 24. 8-17. 10.24985/ijass.2012.24.1.8.

43. Tjelta, Leif Inge. (2016). Review article The training of international level distance runners Leif Inge Tjelta University of Stavanger, Department of Education and Sports science, N-4036, Stavanger, Norway E-mail: leif.i.tjelta@uis.no International Journal of Sports Science & Coaching, 11(1), Jan/Feb 2016. Accepted for publication, 27.03.2015. International Journal of Sports Science & Coaching. 11.

44. Treff, G., Winkert, K., Sareban, M., Steinacker, J. M., & Sperlich, B. (2019). The Polarization-Index: A Simple Calculation to Distinguish Polarized From Non-polarized Training Intensity Distributions. *Frontiers in physiology*, *10*, 707. https://doi.org/10.3389/fphys.2019.00707

45. Tucker, R., Lambert, M. I., & Noakes, T. D. (2006). An analysis of pacing strategies during men's world-record performances in track athletics. *International journal of sports physiology and performance*, *1*(3), 233–245. https://doi.org/10.1123/ijspp.1.3.233

46. Whittemore, R., & Knafl, K. (2005). The integrative review: updated methodology. *Journal of advanced nursing*, *52*(5), 546–553. https://doi.org/10.1111/j.1365-2648.2005.03621.x