

Habits of Spanish and European athletes on altitude training: Do all methods work equally well?

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ABSTRACT

Objective: The training context of athletes from different locations can affect their altitude training camps. The aim of this study was to compare the habits of Spanish and European athletes during high altitude training camps. **Methods:** Descriptive analysis using questionnaires was conducted to investigate the altitude training practices of elite European athletes ($n = 28$) compared with Spanish athletes ($n = 35$). Moreover, all variables were assessed with an analysis of variance (ANOVA). **Results:** The most commonly method used by athletes was Live High - Train High (LHTH). Most Spanish athletes train at altitudes above 2000m, while European athletes train at 1800m. The European athletes group usually compete 2-3 days after the camp, while the most Spanish athletes compete 3 weeks after the camp. In both groups, the feeling of improved performance after the camp was similar. Spanish athletes had higher feeling of fatigue and more sleep problems than European athletes during the training camp ($p < .005$) while the Europeans have a better feeling at the end of the camp. **Conclusion:** Spanish athletes had similar habits to those of athletes from the rest of Europe. The main differences between groups were that the feeling of fatigue at the end of the altitude periods and the sleep problems during the camp. These subjective feelings during the training camp may affect the fact that Spanish athletes preferred to compete up to three weeks after the camp while European athletes preferred to compete in the first 2-3 days after the camp.

Keywords: Performance analysis, Curvilinear sprint, Hip strength, Reactive strength, Vertical jump, Soccer.

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INTRODUCTION

Altitude training began to be used in the 1960s with the aim of improving performance of elite athletes when competing at sea level (Pugh, 1967). The first method used was known as "*Live High - Train High*" (LHTH) (Levine & Stray-Gundersen, 1992), in which athletes live and train at altitude. This method is based on using the whole day with a reduction of the partial pressure of oxygen (PO_2), known as Hypobaric Hypoxia, which is achieved by decreasing the atmospheric pressure, maintaining the same concentration of O_2 in the air (Madaria, 2019). The main limitation of this method is that athletes were not able to train at an intensity equivalent to sea level, due to the reduction of maximum volume of oxygen (VO_{2max}) as a result of the decrease in PO_2 , impairing pulmonary diffusion and O_2 supply to tissues (Wilber, 2007). For this reason, years later another method known as "*Live High - Train Low*" (LHTL) was designed (Levine & Stray-Gundersen, 1997). This method focuses on living all day at altitude and going down to the track at sea level to perform the heaviest workouts, avoiding the problems of the LHTH method. Moreover, in recent years, some protocols have been designed to simulate altitude using tents with N_2 dilution and O_2 filtration, achieving Normobaric Hypoxia, which is produced by a reduction in the O_2 concentration of the air without changing the atmospheric pressure (Levine, 2002). With these methods, athletes now have a wide range of protocols to improve performance depending on their goals and contextual situations (Girard et al., 2023).

The main goals of altitude training is activate the transcription factor called hypoxia-inducible factor 1 (HIF-1) (Semenza, 2004) which has proven to increase blood O_2 transport capacity (Hauser et al., 2017; Robertson et al., 2010), by intervening in glucose uptake, lactate metabolism and neuromuscular changes (Park & Nam, 2017) and improve glucose transport and pH regulation (Gore et al., 2007; Sasaki et al., 2000). All of these changes have been shown to improve middle-distance and long-distance events running performance (Stray-Gundersen et al., 2001).

Regardless of the method, it is required to accumulate a minimum of 3-4 weeks at an altitude of 2000-2500 meters above sea level, or 12-16 hours per day at 2500-3000 meters using simulated altitude for 4 weeks (Park et al., 2017; Wilber et al., 2007). Moreover, repeated and interspersed use of 1 to 2 week hypoxia periods with periods of sea level training can also be used because it produces faster acclimatization through "*hypoxic memory*"; making physiological adaptations appear earlier (Mujika et al., 2019). Another important factor to control in the planning of high-altitude training camps is how long before competition to finish the high-altitude training. It appears that athletes have two periods of performance enhancement. A first one of "*immediate performance window*" (first few days) when returning from a stay at altitude, followed by a "*second window*" (3 - 4 weeks after high altitude training camp) in which performance is optimal, after which performance would decrease (Chapman, Laymon Stickford, et al., 2014; Millet et al., 2010) due to not maintaining the adaptations achieved by altitude. Moreover, there are different factors that can influence running performance during the high-altitude training camps such as iron levels, sleep disturbances, fatigue, hydration status, illness, overreaching and overtraining states (Girard et al., 2023). It is therefore important to monitor these and make individual adaptations to the athlete's training plan if necessary (Hooper & Mackinnon, 1995). Therefore, the context where the high-altitude training camp takes place is a determining factor. Historically, European athletes have performed their high-altitude training stays in Font-Romeu or St. Moritz with heights above 1800m. However, Spanish athletes usually use Sierra Nevada (2300m altitude) but with the facilities of the city of Granada very accessible at an altitude of 740m. This makes it easier to use the LHTL method compared to other European cities. Therefore, there are many variables to control during altitude training planning that may be affected by the context. However, different combinations of these methods could obtain similar results (Millet et al., 2010). The aim of this study was to compare the habits of Spanish and European athletes during high altitude training camps.

METHODS

Design

A descriptive analysis using questionnaires was conducted to investigate the altitude training practices of elite European athletes compared with Spanish athletes.

Participants

63 (41 men and 22 women) international athletes voluntarily participated in the study. Of these 35 were Spanish and 28 from other European countries. Only professional athletes, ranked in the top 5 of their national championship or who have competed in an international championship during the 2023/2024 season, were surveyed. According to the classification system suggested by McKay et al. (McKay et al., 2021), all athletes in this study were categorised as tier 4 (elite/international athletes).

The athletes included in this analysis were an average of 25.7 ± 9.2 years old. Thirteen athletes (20.6%) were top-5 of the senior national championship, sixteen athletes (25.4%) had competed in the European Championship or European Cup's and thirty-four (54%) participated in the 2024 Paris Olympic Games (Table 1). The athletes included in this analysis were from Spain (35 athletes), Ireland (3), United Kingdom (4) Germany (3), Sweden (5), Norway (1), Finland (1), Netherlands (1), Austria (9), Luxemburg (1), Hungary (1) and Poland (1).

Table 1. Descriptive characteristics of the participants included in the study.

	Men	Women	Under20	Under23	Senior	Middle-distance	Long-distance	National Champ.	European Champ.	Olympic Games
Spanish	24	11	1	8	26	11	24	8	17	10
Europeans	17	11	1	4	23	8	20	5	6	17

Procedures

Questionnaires were created *ad hoc* for this research after the validation by a group of three experts. The final version of the questionnaire was developed using "Google Forms". Athletes were instructed to answer the questionnaires regarding 2023/2024 season. This questionnaire has been included as an annex (Annex 1).

The first section of the questionnaire included questions about gender, nationality, age, category, athletic discipline, championships they have participated in this season and high-altitude training method they used in the season. The second section contained questions about habits of altitude training like periodisation and programming, localisation where they do it, and other relevant details such as performance tests, recovery practices, conditioning, nutritional and psychological aspects.

The questionnaire was sent directly to the athletes with the help of the Royal Spanish Athletics Federation (RFEA). The message provided detailed instructions on how to fill out the questionnaire, the format of the questionnaire, and the main sections it encompassed. As a result of this systematic approach, responses from a total of 63 athletes were collected through the Google Forms platform.

Statistical analysis

Data from the questionnaires was extracted into an Excel spreadsheet. Data are presented as relative and absolute frequencies (% , n). To analyse the frequency in each category, contingency tables were used. All

variables were assessed with an analysis of variance (ANOVA). Statistical analyses were carried out using SPSS, Version 28 (IBM Corp., Armonk, NY, USA).

RESULTS

Athletes' altitude training habits

The method most used by athletes was LHTH (57.14%), especially in European athletes (60.7%) compared to Spanish athletes (52.7%). The LHTL method was used only by one European athletes, however, the LHTLH most often was used by 27% of the athletes, being most often in Spanish athletes (27.8%) then European athletes (25%) considered a variant of the previous method. Finally, 1.6% athletes used the LLTH method and 4.76% of athletes opt to use simulated hypoxia.

In relation to the location of the high-altitude camps, the most of Spanish athletes carried them out in Sierra Nevada (Spain, 2300 m) (42.85%). Font - Romeu (France, 1700 m) was the place where 21.42% of European athletes used compared to 28.6% of Spanish athletes, and St Mortiz (Switzerland, 1800 m) was the place where 42.9% of European athletes used compared to 5.7% of Spanish athletes. Other less popular destinations were Iten (Kenya, 2400m), where 17.8% of Europeans trained compared to 0% of Spanish, Dullstroom (South Africa, 2100m), where 10.7% of Europeans trained compared to 2.8% of Spanish, Ifrane (Morocco, 1700m), where 0% of Europeans trained compared to 8.5% of Spanish and Navacerrada (Spain, 1800m), where only 8.5% of Spanish trained and no Europeans. On the other hand, only 2.8% of Spanish and 7.14% of Europeans used artificial hypoxia methods. Figure 1 shows a summary of the training camps chosen by the surveyed athletes.

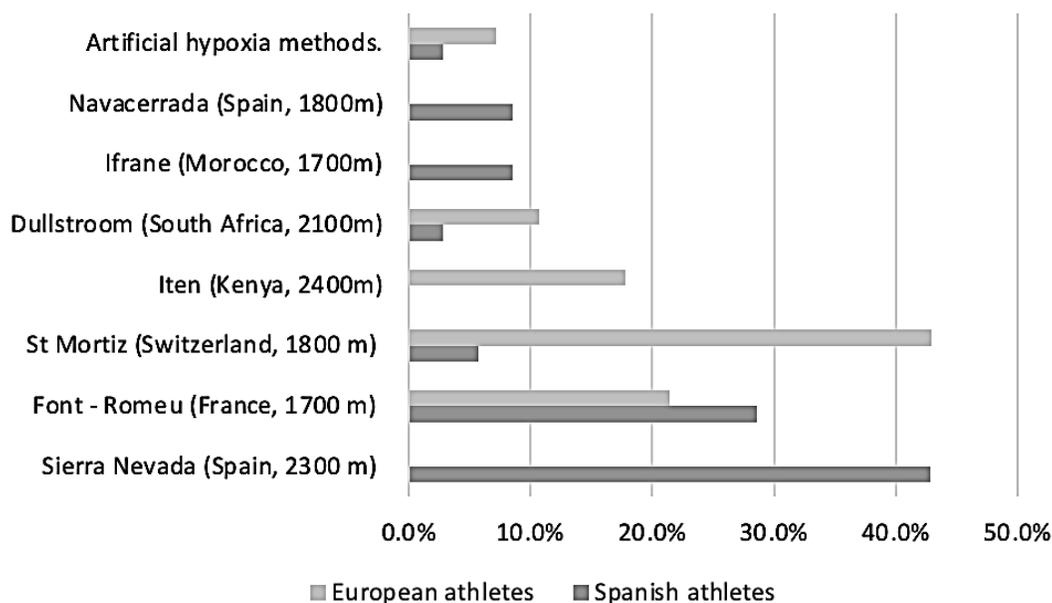


Figure 1. Summary of training camps places chosen by surveyed athletes.

Regarding the time duration that these altitude camps last, the most of them (60% of Spanish and 57.1% of Europeans) dedicated three weeks. However, 25.7% of Spanish and 25% of Europeans spent 4 weeks and 2.8% of Spanish and 7.14% of Europeans spent 5 weeks or more compared to (2.8% of Spanish and 3.6% of Europeans) who spent 2 weeks. Athletes who used simulated hypoxia, used it 12-15h for 3 weeks to 10 weeks.

The most of athletes (57.14%) have had two or more training camps during the 2023-2024 season and the subsequent camps have been shorter only in the 13.9% of them. It is more common for European athletes (71.4%) than the Spanish ones (45.7%). The second and the third camps were shorter than the first one in the 11.8% of Spanish athletes and the 51.8% of the European athletes. Part of them planned the high-altitude training camp before the most important competition of the year (29.3%) or before the competition where to make the requirement that allowed them to go to the competition they were aiming for (18.34%), while 34.9% planned them before both competitions. Only 17.46% used altitude training camps to increase their general fitness during the season.

Comparing the increase in sporting performance, Spanish long-distance runners show an 4.6% improvement in performance on average compared to the pre-contest competition and European athletes show an improvement of 4.1%. With respect to the middle-distance athletes, the Spanish athletes show an 3.4% improvement in performance respect to their previous performance and the European athletes 2.8%. On the other hand, long-distance and middle-distance athletes who trained above 2000m altitude improved their performance in 4.5% and 3.2% respectively; compared to those who trained below 2000m altitude who improved their performance in 4.2% and 3% respectively.

At the end of the high-altitude camp, 54.3% of the Spanish and 78.6% of the Europeans felt they were in optimal shape to compete, compared to 45.7% of the Spanish and 21.4% of the Europeans who were tired and not able to compete. In addition, we analysed the feeling of lightness or easy felt by the athletes during training at different stages of readaptation after the training camp, classifying them from 0-10, with 0 being very heavy and tired and 10 being very light. The average of the European athletes was 5.8 and the average of the Spanish athletes was 5 during the first 4 days after the training camp. At 10 days after the end of the training camp, the average for the Europeans athletes was 6.1 and the average for the Spanish was 6.4 and at 21 days and until the end of the camp, the average for the European athletes was 7.3 and 8 for the Spanish athletes. Therefore, there was a group of athletes (42.9% Spanish and 21.42% European) who rated their rest falling >9 points. With respect to the feeling of fatigue at the end of the camps, we found statistically significant differences ($p < .05$) between the two groups.

Most athletes (74.3% Spanish and 71.4% European) thought that physiological adaptations were present for at least 3-4 weeks. It was evaluated from 0-10 how much they thought they improve due to altitude training, being 0 nothing and 10 everything thanks to this method, and how much placebo effect they thought this method has on them, being 0 nothing and 10 a lot. The mean scores for Spanish athletes were 6.6 and 6 respectively and 7 and 4.9 for European athletes.

Referred to days before the competition they finish the high-altitude camp, the 22.8% of Spanish while the 64.28% of Europeans finished 1 to 3 days before; 20% of Spanish and 21.4% of Europeans finished 7 days before; 14.3% of Spanish and 35.7% of Europeans competed 2 weeks after the camp, 11.4% of Spanish and 7.1% of Europeans competed 3 weeks after the camp and finally, 2.7% of Spanish and 7.1% of Europeans competed 4 weeks or more after the high-altitude camp.

Characteristics of athlete's high altitude training

54.2% of Spanish athletes recognised that they did more km during high altitude camps compared to 46.4% of European athletes. Regarding the intensity of workouts, 34.3% of Spanish and 46.2% of Europeans said that trainings were harder (in terms of amount of physical effort), 48.6% of Spanish and 35.7% of Europeans said that they were similar compared to 17.1% of Spanish and 17.9% of Europeans who said that they were

less intense. However, the most of them (94.3% of Spanish and 96.4% of Europeans) have found that their workouts were slower at altitude than at their usual residence.

On the other hand, most of the athletes showed a high level of fatigue during the first days of the training camp, the average was 6 out of 10 for the Spanish and 5.1 out of 10 for the Europeans. The average duration of these symptoms were 4.8 days for Spanish and 5.5 days for Europeans.

Other aspects of high-altitude training

Regarding sleep disturbances produced during high altitude training, the number of sleep disturbances produced in the athletes surveyed was evaluated from 0-10, with 0 being none and 10 being very often. The mean was 5.8 for Spanish and 4 for Europeans. Here, too, there were statistically significant differences between the two groups. Only 34.3% of the Spanish athletes and 28.6% of the European athletes became ill during a training camp. Conversely, 62.85% of Spanish athletes and 75% of European athletes carry out the high-altitude camps in groups. The mood of the endurance athletes during the camp was assessed on a scale of 0 -10, with 0 being very discouraged and 10 being very happy. The average score of the Spanish athletes was 7.6 and of the European athletes 7.75. The average score of the athletes doing the camps alone was compared with the average score of the athletes doing the camps in a group, being 7.9 and 7.5 respectively.

In relation to the supplementation used by each group of runners, 5.7% of the Spanish and 82.1% of the Europeans take iron supplements. 88.6% of Spanish and 75% of Europeans increased their intake of carbohydrates and 94.3% of Spanish and 75% of Europeans increased their intake of water, the average consumption being 1.6 L more in Spanish and 1.64 L more in Europeans. In addition, 57.1% of Spanish and 50% of Europeans take supplements with Magnesium, Vitamin D, omega 3, salts, Protein, creatine ad betalanine during training.

DISCUSSION

The aim of this study was to compare the habits of Spanish and European athletes during high altitude training camps. The main results were significant differences in the feeling of fatigue at the end of the camp and the sleep disturbances during the camp between groups, with no significant differences in the rest of the variables measured between the groups.

Athletes' altitude training habits

The method most used by all athletes was the LHTH (57.14%), especially in European athletes (60.7%) compared to Spanish athletes (52.7%) but without significant differences. Thus, the different contexts of the sites where the high altitude camps were held did not influence the type of camp that the participants performed (Levine & Stray-Gundersen, 1992). This method has shown good results in improving athletic performance, however it was found that the intensity of training was lower than at sea level, due to the decrease in partial pressure of O₂ and SatO₂, affecting pulmonary diffusion and reducing arterial O₂ content and O₂ supply to tissues, and therefore VO_{2max}, which will start to decrease between 300 and 800 m altitude (Wehrin et al., 2006). Therefore, when high-intensity exercise is performed, such as the repeats work outs, the recovery time between these should be longer to maintain the same intensity as at sea level, "detraining" the anaerobic component (López Calbet JA., 2006; Noakes et al., 2001; Subiela, 2014).

To solve this, the LH TL method increased its popularity at the beginning of this century. However, this method was used only by 3.57% of European athletes. The aim of living at altitude and training at sea level is inducing

HIF-1 synthesis, and maintaining adequate training intensity. This is in agreement with studies by different researchers where they found that RBCV and VO_{2max} increased with LHTH and LHTL intervention, but performance in the 5000 ml competition improved more in the LHTL group (Stray-Gundersen et al., 2001; Wehrlin et al., 2006). For these reasons, it appears that LHTL is the most common in the literature if the goal is to compete at sea level in the next 4 weeks post training camp, as the benefit derived from hypoxic training depends on the balance between achieving physiological adaptations and achieving adequate training volume and intensity (Brocherie et al., 2015; Sinex & Chapman, 2015). However, only the 1.57% of the total athletes surveyed used it. It was used by 27% of the athletes, similar in Spanish athletes (27.8%) and European athletes (25%). It is considered a variant of the previous method and it has been proposed with the aim of reducing displacement and facilitating rest for endurance athletes. This methodology is based on prioritising descent to lower altitudes for higher intensity sessions, while remaining at moderate altitude for training at race pace (Mujika et al., 2019), achieving and physiological changes similar to other protocols at altitude and an increase in performance compared to the control group, suggesting that the use of this method is suitable for improving endurance performance (Sinex & Chapman, 2015).

Finally, 1.6% athletes used the LLTH method and 4.76% of athletes used the simulated hypoxia. These methods are the least effective for increasing running performance (Wilber, 2007), as the time in hypoxia may not be sufficient to induce an increase in RBCV, thus athletes do not perceive the performance improvement of these methods and prefer not to use them.

The most used places were Sierra Nevada (Spain, 2300 m) for the Spanish athletes and St Mortiz (Switzerland, 1800 m) for the European athletes. Moreover, Font - Romeu (France, 1700 m) is in third place and was attended by a similar percentage of both groups. Traditionally, the optimal altitude has been considered to be that which has sufficient altitude to induce the desired acclimatization effect, manifested by a significant and sustained increase in serum erythropoietin and subsequent accelerated erythropoiesis, without being so high that athletes are unable to recover from daily training. Different studies have found that after 4 weeks of LHTL, VO_{2max} increases in runners living at altitudes greater than 2085 m and performance improves significantly (Wilber et al., 2007). However, many of the paces used by the participants have an altitude of less than 2000 m. For example, Font - Romeu (France, 1700 m), St Mortiz (Switzerland, 1800 m), Ifrane (Morocco, 1700m) and Navacerrada (Spain, 1800m). On the other hand, most of the participants, regardless of their place of origin, used places with higher altitude like Sierra Nevada (Spain, 2300 m), Iten (Kenya, 2400m) and Dullstroom (South Africa, 2100m). Based on this data, these paces seem to be the most suitable to improve running performance. The 45.65% of Spanish athletes and 28.5% of European athletes train there.

Regarding the duration of the high-altitude camp most of the participants (60% of Spanish and 57.1% of Europeans) dedicated three weeks and the 28.5% of Spanish and 32.14% of Europeans spent 4 weeks or more without differences between groups. Only the 2.8% of Spanish athletes and 3.6% of Europeans athletes spent 2 weeks. Several studies have showed that hypoxic exposure of less than 2 weeks duration is unlikely to increase red blood cell volume (RBCV) (Ashenden et al., 2001; Birkeland et al., 2000); rather, a minimum of 3-4 weeks at an altitude of 2000-2500 m above sea level, or 12-16 hours per day at 2500-3000 m using simulated altitude for 4 weeks seems necessary for accelerated erythropoiesis (Chapman, Karlsen, et al., 2014; Saunders, Pyne, & Gore, 2009; Wilber et al., 2007). Indeed, the effect on RBCV after 3-4 weeks of exposure to moderate altitude is similar in magnitude to recombinant human Eritropoyetin injection at low altitude (Brugniaux et al., 2006; Park et al., 2017; Wilber et al., 2007), so it seems to be the optimal duration for high altitude training camps. Therefore, based on the literature, the most of the participants surveyed have

a camp long enough to induce physiological adaptations (Brugniaux et al., 2006; Park et al., 2017; Wilber et al., 2007).

The most of European athletes (71.4%) have had two or more training camps during the 2023-2024 season compared with the Spanish ones (45.7%) without significant differences between groups. In the European athlete's group (51.8%) was more frequent to do a second and a third camps shorter as opposed to 11.8% of Spanish athletes who shorten their duration. It has been shown that the repeated use of 1-2 week altitude camps interspersed with periods of training at sea level can also improve performance in elite endurance athletes (Daniels & Oldridge, 1970; Saunders, Pyne, Gore, et al., 2009), due to faster acclimatisation through "*hypoxic memory*"; causing physiological adaptations to appear earlier (Mujika et al., 2019). This method of training seems to be more common in European countries. If it would be adapted by Spanish athletes, they could spend less time in camps and theoretically obtain similar results.

Most of the participants planed the high-altitude training camp before the most important competition of the year (29.3%) or before the competition where to make the record that allowed them to go to the competition they were aiming for (18.34%), or both (34.9%). Only 17.46% used altitude training camps to increase their aerobic capacity during the season. But, before the main competition of the calendar, it is important to determine how long before the main competition to finish the camp. Researchers have observed three phases after the return to sea level, in which several windows are optimal for competition depending on the athlete's response: (I) A positive phase observed during the first 2-4 days which is not present in all athletes; (II) A phase of progressive restoration of training volume and intensity level, where the probability of good performance is reduced; (III) 15-21 days after return to sea level, a phase characterised by a plateau in fitness (Millet et al., 2010).

The 22.8% of Spanish and the 64.28% of Europeans finished the camp 1 to 3 days before the main competition, using the first phase described above. The immediate positive effects of phase I are mainly due to the haemodilution resulting from the return to sea level and the persistence of ventilatory adaptations to altitude training (Millet et al., 2010). Because of these adaptations, it may be an ideal first "*window*" of time to compete, although it will not be the best time in all cases as it presents great individual variability (Millet et al., 2010). In fact, 45.7% of the Spanish and 21.4% of the Europeans athletes tested indicated that they were "*very tired*" at the end of the camp; compared to 54.3% of the Spanish and 78.6% of the Europeans who were in optimal conditions to compete. Also, the average of the feeling of lightness or easy felt by the Spanish athletes was 5.0/10 and 5.8/10 by the Europeans ones during the first 4 days after the end of the training camp. These results show that reason this phase could be optimal in some athletes.

In order to mitigated the fatigue produced during the camp (Chapman, Karlsen, et al., 2014), a typical strategy is that 2-5 days before the phase I, gradually reduce the volume and intensity of training to levels similar to those at sea level (Millet et al., 2010). Both evaluated groups used this phase (phase II from the 5th to the 13th day (Millet et al., 2010)) in a similar way, where only the 20% of Spanish and 21.4% European athletes competed. The average of the feeling of rest at 10 days after the camp was for the Spanish athletes 6.4/10 and 6.1/10 for the Europeans. This phase would be a suboptimal time to compete because there is a decrease in performance that could be related to the energy cost and the loss of the neuromuscular adaptations induced by altitude training, produced by neocytolysis. To address this and try to minimise the effects of this process, HIF-1 synthesis could be artificially stimulated by 2-3 h microexposures to hypoxia after the return from altitude training either naturally or artificially (Garvican et al., 2012; Wilber et al., 2007).

The improvement in muscle adaptations and ventilation after several days at sea level, together with the additional increase in O₂ transport and hypoxic ventilatory responses, characterizes phase III (from the 14th to the 21st day after the camp) and which is an optimal time to compete (Millet et al., 2010). In this phase, the 14.3% of Spanish and 35.7% of Europeans athletes competed 2 weeks after the camp and the 11.4% of Spanish and 7.1% of Europeans competed 3 weeks after. Although there was no significant difference in the number of athletes who competed 2 or 3 weeks after the camp between the Spanish and European groups, the majority of Europeans preferred to compete 2 weeks after the camp and also showed a lower feeling of rest (7.3/10 vs. 8/10 in European athletes vs. Spanish athletes). Possibly, competing in week 2 after the training camp causes greater fatigue than in week 3 after the camp and that is why the feeling of rest was greater in the Spanish athletes. However, there was a group of athletes (42.9% Spanish and 21.42% European) who rated their rest feeling >9 points. Therefore, the recovery of the camp at 3 weeks was higher in Spanish athletes.

Finally, only the 2.7% of Spanish athletes and 7.1% of Europeans athletes respectively compete after 21 days. At this point, theoretically, the physiological adaptations of the altitude would not be present (Millet et al., 2010). So, the most part of the athletes (77.3% and 71.5% respectively) competed in an optimal window. However, it is important to note that there is considerable individual variation in physiological responses to altitude training in terms of haemoglobin mass, as well as performance; probably due to the genetic predisposition of each individual (Chapman, 2013; RF Chapman et al., 1985). This could have affected the existence of significant differences in this last phase in the feeling of rest between groups.

Characteristics of athlete's high altitude training

Most of Spanish athletes (54.2%) recognised that they did more kilometres during high altitude camps compared to 46.4% of Europeans, although without significant differences between groups. Moreover, a large group of European athletes (46.2%) indicated that the trainings were heavier (higher physical effort), compared with the 34.3% of Spanish athletes. During the altitude training camps it is important to control the training load because high altitude causes additional stress on athletes that needs to be carefully managed to avoid overtraining. In addition, during training sessions pacing is difficult to control, because training speeds are slower, as stated by most of the athletes (94.3% of Spanish athletes and 96.4% of European athletes). Therefore, it is advisable to adopt a conservative approach, reducing the overall volume, especially in the first week, where the average fatigue level was 6/10 for the Spanish athletes and 5.1/10 for the European athletes, even if the training method is LHTL. To minimise fatigue and avoid overexertion, modifications in training structure (i.e. altering the exercise-rest ratio by lengthening rest periods during intervals) based on their exercise-related sensations especially during the first week is recommended. (Girard et al., 2023).

Other aspects of high-altitude training

There were significant differences between groups in sleep disturbances produced during high altitude training camps (5.8/10 points for Spanish vs 4/10 points for Europeans). The main difference between the characteristics of the Spanish and European training camps was the altitude of the training plan place. The 45.7% of the Spanish athletes performed the camps above 2,000 metres, compared to 28.5% of the European athletes. Previous studies has described sleep problems at around 2,200 m altitude (Bloch et al., 2015) compared to lower altitudes. This may be due to the compensatory physiological changes, including a hyperventilatory response to arterial desaturation and increased sympathetic activity, with increased heart rate and blood pressure (Vitale et al., 2022), lead to more awakenings, more abnormal breathing, and less deep sleep (Sargent et al., 2013). However, at intermediate altitudes around 1,500m, the likelihood of sleep problems is lower (Vitale et al., 2022). Moreover, the difference in altitude may also explain the fact that

34.3% of Spanish athletes have ever been sick during their camps compared to 28.6% of European athletes, although without significant differences. The infections upper respiratory or gastrointestinal tract infections are more frequent at higher altitudes (*Exercise, immune function and respiratory infection: An update on the influence of training and environmental stress - Walsh - 2016 - Immunology & Cell Biology - Wiley Online Library*, s. f.) since the exposure to hypoxia are able to alter a number of cellular and functional immunologic parameters (Facco et al., 2005).

Referred to the supplements used by the athletes during the camps, the most of the athletes (85.7% of the Spanish athletes and 82.1% of the European athletes) used iron supplements. Iron supplementation is one of the most important aspects of high-altitude camping, as during high altitude camping, there is an increased absorption of iron related to erythropoiesis. Maintaining optimal iron levels in athletes is essential to ensure the physiological adaptations induced by high-altitude training (Garvican-Lewis et al., 2016). In case of iron deficiency, the probability of an altitude-induced increase in haemoglobin mass is minimal. Therefore, the ideal is to normalise the iron level 2 to 3 weeks before the camp and continue supplementation throughout the altitude exposure (Girard et al., 2023).

The 88.6% of Spanish athletes and 75.0% of Europeans increased their intake of carbohydrates during the training camp. This is due to intended to replace muscle glycogen stress, suggesting a greater need from carbohydrates intake during exercise (Michalczyk et al., 2016). Moreover, 94.3% of Spanish and 75.0% of Europeans increased their intake of water, the average consumption being 1.6 L more in both groups of athletes. The hypoxia and low humidity in the air at altitude produce increased respiratory water loss and increased diuresis, often seen in the early response to altitude exposure. This leads to a significant increase in water requirements, while at the same time reducing the sensation of thirst and changes in fluid availability in a new environment. Therefore, during altitude camps there is an increased risk of dehydration, so it is important to increase fluid intake and monitor the athlete (Stellingwerff et al., 2019).

In addition, 57.1% of Spanish and 55.2% of Europeans used supplements with Magnesium, Vitamin D, Vitamin B, omega 3, salts, Protein, creatine, glutamine or betalanine during training. There is currently no clear evidence on nutritional supplements that act as ergogenic aids to improve adaptation or performance at altitude. There are no studies investigating the impact of vitamins B6, B12 and D or glutamine or branched-chain amino acids in athletes at low to moderate altitude. Therefore, whether increased intake of these vitamins and proteins (in the form of supplements) would have additional benefits but future studies are needed (Stellingwerff et al., 2019). However, it should be noted that although these supplements have not been shown to increase performance, those that increase immune system activity would be recommended, due to the decrease in the immune system at altitude (Caris & Santos, 2019).

CONCLUSIONS

Despite the differences in context between Spanish and European athletes in the high altitude training camps, the most frequently method among athletes was LHTH. Moreover, Spanish athletes had similar habits to those of athletes from the rest of Europe regarding training camp periodization. However, it is important to highlight that the most of European athletes and many of the Spanish athletes, train in suboptimal locations (less than 2000m altitude). Regarding the time spent for the camp, most participants carry out camps long enough to induce physiological adaptations. The main difference between groups was that the feeling of fatigue at the end of the altitude periods was greater in the European athletes, which can be explained by the fact that most of the European athletes decided to compete in the 2-3 days after the camp, while the Spanish athletes competed up to three weeks later. In addition, the European athletes had less sleep

problems than the Spanish athletes. However, no statistically significant differences were found in terms of improvements in final race performance.

AUTHOR CONTRIBUTIONS

All authors have contributed to the conception and design of the work, the acquisition, analysis and interpretation of data for the work and revising it critically. All authors approved the final version of the manuscript; they are agreeing to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; and all persons designated as authors qualify for authorship, and all those who qualify for authorship are listed.

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ANNEX 1

This survey aims to collect a series of data that will be used in a study that forms part of a Doctoral Thesis on the physiological changes that take place after high altitude training in long-distance and middle-distance events. It will be carried out by Carlos Campo Beamud, doctor at the HGUCR and directed by Victor Rodrigo Carranza, researcher at the University of Massachusetts and in the Faculty of Sports Sciences in Toledo. The results will be published in June 2024. We thank you in advance for your willingness and collaboration.

It is important for us to carry out the survey between the months of September and October 2023, in order to evaluate the training camps held during the 2022-2023 season.

It is a simple survey that will not take more than 5 minutes.

The answers will be published anonymously and the results will not be shared with anyone outside this study.

Sex

- 1 Man
- 2 Woman

Where are you from?

- 1 Spain
- 2 United Kingdom
- 3 Ireland
- 4 Germany
- 5 Sweden
- 6 Norway
- 7 Finland
- 8 Netherlands
- 9 Austria
- 10 Luxembourg
- 11 Hungary
- 12 Poland

Type of race you practice

- 1 Long distance on the track
- 2 Middle distance
- 3 Both on the track
- 4 Marathon

Principal competition of the season

- 1 Olympic Games
 - 2 World Championship
 - 3 European Championship / European cups
 - 4 National championship
-

Where do you usually train at altitude?

(E. g.: Sierra Nevada, Font Romeu... // I use simulated or artificial hypoxia)

1 Sierra Nevada (2300 m)

2 Font - Romeu (1700 m)

3 St Moritz (1800 m)

4 Iten (2400 m)

5 Dullstroom (2100 m)

6 Navacerrada (1800)

7 Ifrane (1700 m)

8 Hypoxia artificial

If you have indicated another location, please specify what is the place where you do your altitude training camp and the altitude (Example 2200 m) if it is possible

Number of altitude training camp during this season

1

2

3 or more

IF you checked 2 or 3 or more altitude training camps during the season, indicate how long the 2nd and / or 3rd concentration lasts.

All my altitude training camps last the same length

The first high altitude concentration of the season is the longest, then I decrease the duration of the stay

In case you have marked Life at high altitude / training at high and low altitude; indicate how long the camp lasted, how many days you trained low altitude and what kind of training you did (if you have done several and in different ways you can indicate it).

(Eg: 1st training camp: 3 days out of 21 to do quality sets // 2nd camp: 14 days and I didn't go down)

Time in a competition before and after high altitude training (e.g. 1500 3:42 and 3:38).

(if you can write two even better)

What criteria does your coach use to decide when to do these altitude training camps?

1 Before the most important competition of the season

2 Before a competition where you can do the mark to qualify to some championship (the minimum)

Option 1 and 2

None of the above

If you have chosen none of the above, please indicate when the concentration is scheduled to take place.

How many days does your high altitude concentrations last?

If it is intermittent simulated hypoxia, how many hours a day do you dedicate to it and for how many days?

How many days before the competition do you come down from altitude?

(If you have done several this season, please indicate how long before each one)

Do you train more kilometres per week during the high altitude training camp than at your usual training site?

Yes

No

Are the work out / repeats training performed at altitude more intense (requiring more effort) or less intense than at your usual training site?

More intense

Less intense

Similar

Are the sets performed at altitude faster or slower than at your usual training site?

Faster

Slower

Indicate on a scale of 0 - 10 how fatigued you feel at the beginning of the concentration at altitude.

0 1 2 3 4 5 6 7 8 9 10

Indicate how many days this feeling of fatigue lasts.

1 2 3 4 5 6 7 8 9 10

What are your feelings at right at the end of the high altitude rally?

Indicate on a scale of 0 -10 how "light" or "easy" you feel when running during:

The first 4 days

0 1 2 3 4 5 6 7 8 9 10

The first 10 days

0 1 2 3 4 5 6 7 8 9 10

The first 14 days AFTER the training camp

0 1 2 3 4 5 6 7 8 9 10

Could you please specify your shooting pace:

1. At your usual residence without altitude
2. At altitude the first 4 days
3. At altitude the first 10 days
4. On return to your usual residence without altitude

How long do you feel that the physiological "improvements" achieved by high altitude training last?

1 week

2 week

3 week

4 week

5 week or more

Indicate on a scale of 0 - 10 how much you think your sporting performance is enhanced by training at altitude.

0 1 2 3 4 5 6 7 8 9 10

Indicate on a scale of 0 - 10 how much of a placebo effect you think having trained at high altitude has on your ability to compete.

0 1 2 3 4 5 6 7 8 9 10

Indicate on a scale of 0 - 10 the intensity of sleep disturbances that you experience during concentration at altitude.

0 1 2 3 4 5 6 7 8 9 10

Do you take iron supplements during high altitude training?

Yes

No

Does your usual carbohydrate intake increase during high altitude training?

Yes

No

Does your usual intake of water or other liquids increase during high altitude training?

Yes

No

Could you please specify how many more litres of hydration you consume?

Do you take any other supplements during the high altitude training (if yes, please indicate which one)?

Did you get sick or constipated more easily during the high altitude training camp than in your usual residence?

Yes

No

Have you been injured more easily during the high altitude training camp than in your usual residence?

Yes

No

Do you usually do high altitude training camp in a group with other colleagues or do you do them on your own?

In group

Alone, with my coach and/or other athletes with whom I do not have a relationship.

From 0-10 how is your mood during the concentration?

0 1 2 3 4 5 6 7 8 9 10

