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Original Article

Changes in anaerobic capacity and blood morphological and biochemical indicators after hypoxic training in an international master class female hurdling athlete

ŁUKASZ TOTA[1], TOMASZ PAŁKA[2], MAŁGORZATA MORAWSKA-TOTA[3]
[1,2]Department of Physiology and Biochemistry, University of Physical Education in Krakow, Krakow, POLAND
[3]Department of Sports Medicine and Human Nutrition, University of Physical Education in Krakow, Krakow, POLAND

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Abstract:
Problem statement: In training load periodisation, effective stimuli are pursued to improve physical capacity. The study assessed the impact of 21-day hypoxic training on anaerobic capacity, as well as blood morphological and biochemical indicators in an international master class hurdler. **Approach:** The study involved a 21.5-year-old female junior world champion in indoor 60-m hurdling (2017, Toruń, Poland). We analysed somatic and physiological, as well as blood morphological and biochemical indicators. The Wingate test assessed anaerobic capacity, and the graded test evaluated aerobic capacity. During the preparation period, the hurdler trained at 223 m a.s.l. and stayed in an oxygen tent simulating high altitude for 3 weeks (12.1 ± 0.3 hours per day on average). We applied the graded test in the initial observation period. The Wingate test, preceded by collecting blood for indicator evaluation, was performed twice: before including hypoxia in the training and 2 weeks after its completion. **Results:** In the beginning, the athlete was characterised by a body height of 180.0 cm, body weight of 64.0 kg, lean body mass of 55.3 kg, maximum oxygen uptake of 2.79 $L \cdot min^{-1}$ (43.6 $mL \cdot min^{-1} \cdot kg^{-1}$). After 14 days of hypoxia, the concentration of red blood cells equalled 4.96 million$\cdot \mu L^{-1}$, of haemoglobin: 14.9 $g \cdot dL^{-1}$, of reticulocytes: 18.7‰. The mean power in relation to body mass increased by 9.8% and the peak power in relation to body mass by 7.01%; lactate maximum concentration raised to 16.9 $mmol \cdot L^{-1}$. **Conclusions:** The 3-week 'live high and train low' training improved anaerobic capacity and blood morphological and biochemical indicators.
Key words: live high and train low; red blood cells; haemoglobin; reticulocytes

Introduction

Athletes need new and effective training impulses to constantly improve their physical capacity. The use of hypoxia in endurance training has become a common practice and many researchers (Carr et al., 2019; Tota et al., 2014) have confirmed its efficacy. Within the existing literature, few examples refer to hypoxic training effectiveness in improving anaerobic capacity (Billaut et al., 2012; Gatterer et al., 2019). There is scarce research on the inclusion of hypoxia in training periodisation in athletes practising disciplines with a predominance of anaerobic processes (e.g. sprint running) that would simultaneously analyse blood morphological and biochemical indicators. The need for further investigation into karate athletes' adaptive capacity under hypoxic conditions was highlighted by Rovniy et al. (2017). The specificity of the competition effort among karate athletes is based on anaerobic processes and speed and power abilities. The inclusion of hypoxic training in the training process of these athletes contributed to the improvement of their anaerobic capacity (Rovniy et al., 2017).

The motor skills that contribute to high performance in 60- and 100-m hurdling involve speed, speed endurance, strength, and technique. Depending on the training phase, training loads are applied with maximum and supra-maximum intensity, and rest periods between individual tasks change, which disturbs homeostasis to varying degrees. Therefore, the ability to repeat sprints during the training period is essential to induce the desired super-compensation effect in sprinters (Bompa & Haff, 2010).

The mechanisms responsible for improving physical capacity in endurance athletes mainly involve increasing the volume of red blood cells, which enhances oxygen transport to the muscles and the exercise economy (Schmitt et al., 2006; Wehrlin et al., 2006). In turn, in athletes practising speed disciplines, these mechanisms, as well as the use of hypoxia, are questionable. The improvement of anaerobic capacity in speed and power sports is primarily explained by increased muscle buffering capacity (Gore et al., 2001) and increased activity of glycolytic enzymes (Katayama et al., 2004).

Corresponding Author: ŁUKASZ TOTA, E-mail: lukasztota@gmail.com

As athletes' response to hypoxia is varied (Ainslie et al., 2007a, 2007b), different hypoxia variants are used in training practice. The search for the golden mean has become crucial in optimising and individualising the training process of competitors representing the highest world level.

Training under natural (hypobaric) or artificial (normobaric) hypoxia is undertaken to improve haematological changes (stimulation of erythropoiesis in the bone marrow). The adaptive changes that follow hypoxic training may involve compensatory vasodilation, increased oxygen supply from microvessels to fast-twitch fibres, specific molecular modifications associated with hypoxia-inducible factor 1-alpha, and increased removal of redundant metabolites (Brocherie et al., 2017). Non-haematological changes include improved exercise economy, increased activity of oxidative and glycolytic enzymes, improved skeletal muscle buffer capacity, and raised sodium-potassium adenosine triphosphatase activity in skeletal muscles (Lawler et al., 2019; Millet et al., 2010, 2013; Vogt & Hoppeler, 2010; Wilber, 2011). Moreover, authors investigating the influence of normobaric hypoxia on well-trained athletes have observed numerous metabolic changes already after 14 days of hypoxia (200 hours).

Many different training models combined with hypoxia are used in practice: live high and train high (LH-TH) (classic alpine training); live high and train low (LH-TL); live high and train low and high (LH-TLH); live low and train high (LL-TH); intermittent hypoxic exposure (IHE); prolonged hypoxic exposure (PHE); intermittent hypoxic training (IHT); intermittent hypoxic exposure during interval training (IHIT); and repeated sprint training (RSH) (Hamlin et al., 2017; Millet et al., 2010, 2019b; Wilber, 2011).

In the context of many inconsistent scientific accounts concerning the duration of altitude training, as well as the optimal altitude and training model, the authors attempted to assess the impact of a 21-day combination of training in normoxia supplemented with staying in a tent simulating high altitude conditions on the anaerobic capacity and selected blood biochemical and morphological indicators in a female sprint running athlete.

Material and methods

The subject characteristics

The research referred to a master class female hurdler: junior world champion in indoor 60-m hurdling, bronze medal winner in 100-m hurdling at the European U20 Championships, European youth vice-champion in the same competition, and Polish champion in indoor 60-m hurdling. Her training experience equalled 6.3 years. At the time of research, the athlete was eligible to participate in the XXXII Summer Olympic Games in Tokyo in 2020. The investigated individual provided her written informed consent to participate in the study.

Study design

The exercise stress tests were supervised by a physician. The investigated athlete was advised on the aim and course of the research. A prerequisite for entering the stress tests consisted in presenting valid sports and medical check-up certificates. Owing to low blood iron concentration, the athlete supplemented iron continuously (iron bisglycinate 60 mg, ascorbic acid 80 mg) while remaining under constant medical supervision. The research was performed during the preparatory period of the annual cycle of training for the XXXII Summer Olympic Games in Tokyo in 2020. For the 6 months preceding the investigated training cycle, the athlete lived and trained at an altitude of about 223 m a.s.l. The research project involved 3 stages (Fig. 1).

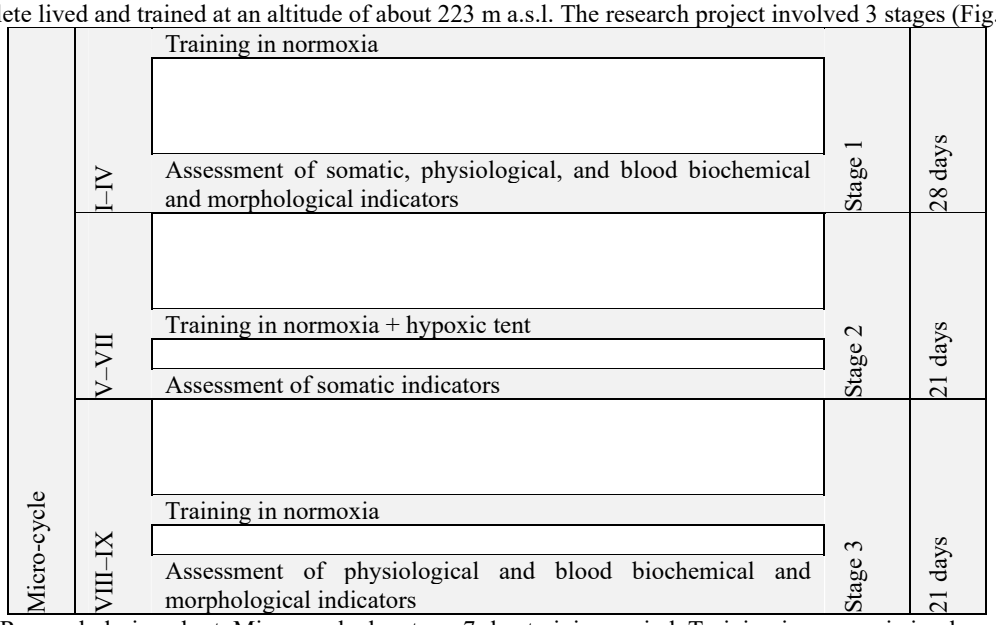

Fig. 1. Research design chart. Micro-cycle denotes a 7-day training period. Training in normoxia implemented at an altitude of about 223 m a.s.l.

During stage 1, after a 4-week training period (micro-cycle I–IV) at an altitude of about 223 m a.s.l. (Krakow, Poland), somatic measurements and stress tests were carried out and blood was collected to assess the morphological and biochemical indicators. The athlete was asked not to change her previous dietary habits throughout the study period.

During stage 2, the 3-week basic training (micro-cycle V–VII) at an altitude of about 223 m a.s.l. (Krakow, Poland) was supplemented with staying and sleeping in a hypoxic tent (Hypoxico, Germany). The tent was equipped with a height generator (Everest Summit II, Germany). The simulated high altitude conditions corresponded to 1850 m a.s.l. during the 1st week, 2400 m a.s.l. during the 2nd week, and 1850 m a.s.l. during the 3rd week. Oxygen volume equalled 17.0% for the altitude of 1850 m a.s.l. and 15.6% for 2400 m a.s.l. During all tent stay sessions, the haemoglobin oxygen saturation (SpO_2) was monitored with a pulse oximeter (Oxygen PO 01, Germany). The mean daily time of staying in the tent during the research was 12.1±0.3 hours. After the completion of the tent stay, the somatic indicators were evaluated.

Stage 3 lasted 2 weeks (micro-cycle VIII–IX) and involved training sessions implemented at an altitude of about 223 m a.s.l. (Krakow, Poland). After its completion, blood was collected for morphological and biochemical tests, and the Wingate test was re-administered.

Somatic indicators assessment

The athlete's body mass was measured with Tanita BIA547 scales and body composition was established by using the electrical bioimpedance method and an AKERN BIA 101 analyser (CE0051 certificate, Council directive 93/42/EEC concerning medical devices). Fat mass, lean body mass, total body water, extracellular water, and body cell mass were also determined.

Physical capacity assessment

The Wingate test was applied to determine the athlete's anaerobic capacity and a graded test served to evaluate aerobic capacity. The latter was performed on a mechanical treadmill, until exhaustion. Exercise stress tests took place with 1-day breaks, starting with the Wingate test. In addition, before and after the tests, lactate concentration in arterialised blood was measured.

Anaerobic capacity assessment: Wingate test

The purpose of the test was to establish the peak power of the lower extremities. The test was applied in its 20-second version, with the load of 6.5% of body mass. It was carried out twice within the follow-up period: after completion of stage 1 and stage 2.

Prior to the test, the subject performed a 5-minute warm-up on a cycloergometer with a 1.0-kg load. The pedalling rate during the warm-up was 60 rpm. In the 2nd and 4th minutes of the warm-up, the participant reached 3-second maximum accelerations and then returned to the 60-rpm pedalling rate. The crucial test was carried out 2 minutes after the warm-up. The athlete's task was to reach the maximum pedalling rate and maintain it for as long as possible.

The test was performed on a cycloergometer (Monark 834E, Sweden), equipped with an instrument to measure the duration of each rotation, connected to a computer. The software used (MCE, JBA, Poland) allowed to determine the following indicators: mean power, total work, peak power, time to obtain peak power, and time of maintaining peak power.

Aerobic capacity assessment: graded test

In order to determine the maximum values of basic physiological indicators, a running test on a mechanical treadmill was performed until exhaustion. The test exertion started with a 4-minute warm-up, during which the subject ran at a constant speed of 8 $km \cdot h^{-1}$, with the treadmill inclination of 1°. Then, every 2 minutes, the running speed was increased by 1.0 $km \cdot h^{-1}$. The test was continued until the athlete refused to proceed with further work because of extreme exhaustion.

The aim of the test was to establish the maximum oxygen uptake (VO_2max) per minute and the second ventilatory threshold.

During the test, the following indicators were recorded by using an ergospirometer (Cortex MetaLyzer R3): minute ventilation, percentage of carbon dioxide in exhaled air, oxygen uptake per minute, carbon dioxide production per minute, respiratory quotient, and ventilatory equivalent for carbon dioxide.

In order to determine the level of the second ventilatory threshold, changes in respiratory indicators that accompanied work intensity increases were analysed. The criteria to establish the second ventilatory threshold were the following: the percentage of carbon dioxide in exhaled air reached its maximum value and then dropped; the ventilatory equivalent for carbon dioxide reached its minimum value and then raised; after exceeding the second ventilatory threshold, a large non-linear increase in lung ventilation was noted (Bhambhani & Singh, 1985; Binder et al., 2008).

The athlete carried out the running exertion on a Saturn 250/100R mechanical treadmill (h/p/Cosmos, Germany) with adjustable belt speed and platform inclination angle. The heart rate during the stress test was measured with a Polar S610i device (Finland).

Blood morphological and biochemical indicators assessment

Before and 2 weeks after the hypoxic tent stay, in accordance with the applicable standards, blood samples were collected from a cubital fossa vein (2 × 6 mL) to EDTA-containing tubes. Blood morphological and biochemical indicators were evaluated with a Sysmex 4500 analyser.

Lactate concentration was determined in the plasma of arterialised blood collected from the pulp of fingers III and IV of the right upper extremity. The blood was collected before the stress tests and 3 and 20 minutes after their completion. Lactate concentration was evaluated with the enzymatic method; a Lactate PAP set (BioMérieux, France) and a Spekol 11 spectrophotometer (Carl Zeiss, Jena, Germany) were applied.

Iron concentration was determined in an independent private research laboratory Diagnostyka (Krakow, Poland).

Body hydration status

Owing to the potential dehydration of the athlete, the morphological and biochemical indicators determined in stages 1 and 3 were adjusted. First, the change in the plasma volume (%ΔPV) was established with the formula by Johansen et al. (1998), and then the Kraemer and Brown (1986) formula served to calculate the adjusted values.

The total blood protein concentration (MBS2540455) was assessed with the immunoenzymatic method (ELISA), by using a DRG-type microplatelet reader (E-Liza Mat 3000, Medical Instruments GmbH, Germany).

Training loads

During stage 1 (micro-cycle I–IV), the athlete completed 20 training sessions of a total duration of 19.7 hours. During observation stage 2, which involved training plus staying and sleeping in the hypoxic tent (micro-cycle V–VII), the athlete completed 16 training sessions of a total duration of 27.7 hours. The total time spent in the tent was 254.1 hours. In this period, the mean SpO_2 level measured on waking up equalled 91.1%. During stage 3 (micro-cycle VIII–IX), the athlete completed 13 training sessions, which lasted 26.5 hours.

Results

Table 1 shows the values of somatic indicators in particular training periods (1st measurement – before the hypoxic tent application, 2nd measurement – immediately after the use of the tent simulating high altitude conditions). No significant changes were observed in the values of somatic indicators in the analysed period.

Table 1. The athlete's somatic indicators

Measurement	BH [cm]	BM [kg]	BCM [kg]	FFM [kg]	FM [kg]	F% [%]	TBW [L]	ECW [L]
1st measurement	180	64.0	32.9	55.3	8.7	13.6	40.2	16.5
2nd measurement	180	63.5	32.3	55.2	8.3	13.1	40.5	16.7

BH – body height; BM – body mass; BCM – body cell mass; FFM – fat free mass; FM – fat mass [kg; %]; TBW – total body water; ECW – extracellular water

Table 2 presents the indicators characterising the athlete's aerobic capacity. VO_2max (43.6 $mL \cdot min^{-1} \cdot kg^{-1}$) was reached at the speed of 13.0 $km \cdot h^{-1}$ and the heart rate of 199·min^{-1}. Oxygen uptake at the level of the second ventilatory threshold (36.4 $mL \cdot min^{-1} \cdot kg^{-1}$) accounted for 83.5% of the maximum value of this indicator.

Table 2. Selected indicators of the athlete's aerobic capacity

Level		t [min]	v [$km \cdot h^{-1}$]	HR [min^{-1}]	VO_2 [$L \cdot min^{-1}$]	VO_2/kg [$mL \cdot min^{-1} \cdot kg^{-1}$]	VE [$L \cdot min^{-1}$]
Stage 1	VT2	8.00	10.0	180	2.33	36.4	77.5
	max	14.00	13.0	199	2.79	43.6	103.6

VT2 – the level of the second ventilatory threshold; max – maximum exertion level; t – test duration; v – running speed with the treadmill inclination of 1°; HR – heart rate; VO_2 – oxygen uptake per minute; VE – minute ventilation

Changes were reported in the indicators characterising anaerobic capacity after the hypoxic tent application. There was an increase in mean power in relation to body mass by 9.8% and in peak power in relation to body mass by 7.01% (Table 3).

Table 3. Selected indicators of the athlete's anaerobic capacity

Measurement	MP [W]	MP [$W \cdot kg^{-1}$]	TW [kJ]	PP [W]	PP [$W \cdot kg^{-1}$]	TOPP [s]	TMPP [s]
1st measurement	644	10.1	12.88	721	11.26	3.92	3.43
2nd measurement	712	11.2	13.93	769	12.11	3.81	3.50

MP – mean power; TW – total work; PP – peak power; TOPP – time to obtain peak power; TMPP – time of maintaining peak power

After the 1st Wingate test, the lactate concentration measured 3 minutes after the test completion equalled 15.9 $mmol \cdot L^{-1}$; after the 2nd Wingate test, it was greater by 1 $mmol \cdot L^{-1}$. The drop in lactate concentration between the 3rd and 20th minute after the anaerobic capacity test completion equalled 44.5% and 52% in the 1st and 2nd Wingate test, respectively (Table 4).

Table 4. The athlete's exertion-associated lactate concentrations

Wingate test						
Parameter	0		3		20	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
La^- [mmol·L^{-1}]	1.31	1.41	15.9	16.9	8.82	8.11
Graded test						
Parameter	0		3		20	
La^- [mmol·L^{-1}]	1.06		11.8		6.17	
$La_3 - La_{20}$ [mmol·L^{-1}]			5.63 (47.7%)			

La^- – blood lactate concentration: 0 – initial, 3 – 3 minutes after the test completion, 20 – 20 minutes after the test completion; $La_3 - La_{20}$ – difference in lactate concentration between the 3rd and 20th minute after the anaerobic capacity test completion: 3 – 3 minutes after the interruption of peak intensity exertion, 20 – 20 minutes after the interruption of peak intensity exertion

Table 5 presents selected blood morphological and biochemical indicators in stages 1 and 3 of the study. An increase was observed in haemoglobin concentration by 1.4 g·dL^{-1}, in mean corpuscular haemoglobin by 2.7 pg, and in reticulocyte concentration of all fractions.

Table 5. The athlete's blood morphological and biochemical indicators

Value	RBC [10^3·mm^{-3}]	WBC [10^3·mm^{-3}]	Hb [g·dL^{-1}]	Hct [%]	MCV [μm^3]	MCH [pg]	MCHC [g·dL^{-1}]
Normal	*3.93–5.22*	*4.3–10.0*	*11.2–15.7*	*34.1–44.9*	*79.4*	*25.6–32.2*	*32.0–35.5*
1st measurement	4.82	6.22	13.5	40.9	82.3	27.0	34.5
2nd measurement	4.99	6.84	14.9	41.6	84.7	29.7	35.1
Value	RET [‰]	LFR [%]	MFR [%]	HFR [%]	IRF [%]	Iron [μmol·L^{-1}]	
Normal	*5.0–20.0*	*89.40–99.50*	*1.8–14.40*	*0.00–2.40*	*5.8–38.5*	*33.0–193.0*	
1st measurement	13.60	92.50	6.70	0.80	7.50	101.6	
2nd measurement	18.70	94.30	11.30	1.40	17.11	114.2	

RBC – red blood cells; WBC – white blood cells; Hb – haemoglobin; Hct – haematocrit; MCV – mean corpuscular volume; MCH – mean corpuscular haemoglobin; MCHC – mean corpuscular haemoglobin concentration; RET – reticulocytes; LFR – low-fluorescence reticulocytes; MFR – medium-fluorescence reticulocytes; HFR – high-fluorescence reticulocytes; IRF – immature reticulocyte fraction

Discussion

The aim of the study was to assess the effect of using a tent simulating high altitude conditions in the preparation cycle on anaerobic capacity, as well as blood morphological and biochemical indicators in a female sprint running athlete. The presented results reflect a case analysis; therefore, correlating them with results obtained by other authors may be questionable. However, one should emphasise that the investigated athlete is a world record holder and multiple national champion, and her training schedule and loads exploit the maximum of her potential. The findings discussed here should be treated as preliminary data for further research to be conducted in a similar methodological pattern that would involve a representative group of athletes practising sprint running disciplines.

The main goal of hypoxic training, regardless of the form applied, is to improve physical capacity. In endurance athletes, the combination of aerobic training and hypoxia produces better results than aerobic training alone (Carr et al., 2019). The increase in blood morphological and biochemical indicators reported in this study seems to significantly translate into improved aerobic capacity of the athlete. Blood oxygen capacity is not a key factor in achieving good sports results in sprinting competitions, but, with the implementation of high intensity training loads and short rest breaks, it can contribute to increasing the efficacy of recovery between tasks, as well as between subsequent training sessions (Bompa & Haff, 2010). This mainly results from the fact that with repeated sprints, which occur in the training periodisation in sprint running athletes, the share of aerobic metabolism increases with each subsequent distance covered (Bishop & Edge, 2006).

One of the most important factors influencing erythropoietin release is the duration of exposure to hypoxic conditions (Knaupp et al., 1992). In training which involves the use of a hypoxic tent, it still remains unclear how long the athlete should stay in the tent and what altitude should be simulated. Improving sports performance at sea level after hypoxic training is attributed to an increase in red blood cell volume and mean corpuscular haemoglobin (i.e. to delivering more oxygen to the working muscles) (Garvican-Lewis et al., 2015), to improving skeletal muscle buffer capacity (Gore et al., 2001), and to producing more adenosine triphosphate (ATP) per molecule of consumed oxygen (Katayama et al., 2004). Some authors (Berglund & Ekblom, 1991) suggest that in endurance athletes, administering recombinant erythropoietin may raise mean red blood cell mass and, consequently, improve VO_2max values and sports performance, regardless of the athletes' sports level.

Saunders et al. (2013) reported that an increase in haematopoiesis and blood erythrocyte and haemoglobin concentrations was correlated with raised VO_2max. However, erythropoiesis is inhibited in individuals with low blood iron concentrations in the course of hypoxia (Stray-Gundersen et al., 1992). This is why the investigated athlete had started iron supplementation long before hypoxia was applied. The study revealed a rise in haemoglobin concentration by 9.4% and in reticulocytes by 27.3%. However, one should still bear in mind that many authors emphasise the individual variability of changes in haematological indices in response to hypoxia (Hauser et al., 2016).

The results of the present study are in line with those obtained by Stray-Gundersen et al. (2001) and Hahn et al. (2001), who observed an increase in haemoglobin concentration >8% after applying LH-TL. Robach et al. (2006) demonstrated that the use of 13-day LH-TL training at simulated altitudes of 2500–3000 m was sufficient to induce a significant increase in red blood cell volume among highly-trained swimmers. Wehrlin and Marti (2006) concluded that living at the altitude of 2500 m and implementing training loads at lower altitudes for 24 days led to an increase in haemoglobin mass and red blood cell volume as compared with athletes living and training at low altitudes. Other studies did not report changes in reticulocyte volume or haemoglobin mass after 12 nights spent at 2650 m (Ashenden et al., 1999) or 14 nights spent at 1956 m (Dehnert et al., 2002).

Many issues related to the considerable variability of responses to hypoxia among athletes still remain unsolved (Millet et al., 2019a). There are many factors described in the literature that might explain the varied reaction of increased haemoglobin concentration to hypoxia. These include body fatigue and the type of training performed before hypoxia application (Garvican et al., 2007), the type of training implemented during hypoxia (Garvican-Lewis et al., 2015), individual erythropoietic response to hypoxia (Friedmann et al., 2005), and the genetic profile (Wilber et al., 2007). In addition, athletes with high haemoglobin concentrations before the onset of hypoxia (>14 $g \cdot dL^{-1}$) present lower gains than those with lower baseline values (Millet et al., 2019a).

It may be assumed that the use of hypoxia conditions will contribute to a more effective execution of training loads among athletes who train sprint running disciplines. This is supported by an increase in anaerobic glycolytic activity (Faiss et al., 2013) and by modified acid-base homeostasis (Nummela & Rusko, 2000), both occurring after hypoxia.

In the present study, the changes in blood morphological indicators were similar to those observed by Muraoka and Gando (2012). These authors proposed the LH-TL model, with the simulated altitude of 2000–3000 m a.s.l. and the hypoxia exposure time of ≥12 hours per day for ≥20 days. In turn, Roberts et al. (2003) reported an increase in anaerobic power at sea level after a week of hypoxia already (8 hours a day), and Muraoka et al. (2004) just after 5 days of hypoxia (2500 m a.s.l., 10 hours per day) in sprinters. These findings remain in line with own results as an increase was recorded in the mean power relative to body mass by 9.8% and in the peak power relative to body mass by 7.01%. Furthermore, the peak lactate concentration after the Wingate test at the end of the observation period increased as compared with the value measured after the 1st test and equalled 16.9 $mmol \cdot L^{-1}$. There was also a faster rate of lactate restitution between the 3rd and 20th minute after completing the anaerobic capacity test.

Hypoxia exposure time and the simulated altitude are debatable, and so are views on the mechanisms by which the LH-TL protocol improves capacity at sea level. Hamlin et al. (2010), who applied the intermittent hypoxia conditioning model (91 minutes per day for 10 successive days), concluded that the observed anaerobic power increase in the group of athletes (n=16) could be partially explained by the raised haemoglobin concentration. Berglund (1992) found an increase in haemoglobin concentration by about 1% among athletes, whereas the present study revealed an increase by 1.4 $g \cdot dL^{-1}$, which equalled 9.4%. In hypoxia, chemoreflex sensitivity increases, which results in raised lung ventilation and, consequently, smaller SpO_2 decreases during the implemented training loads (Katayama et al., 2004). Moreover, at the cellular level, hypoxia can affect changes in mitochondrial energy production by increasing the amount of ATP delivered per 1 mole of oxygen used (Katayama et al., 2004). Hypoxic conditions raise the efficacy of carbohydrate use in ATP resynthesis per 1 mole of oxygen used (Hahn & Gore, 2001). Gore and Hopkins (2005) reported that a 1% increase in capacity at sea level after LH-TH application was a placebo effect. Differences in body response to hypoxia may also result from genetic predisposition (Ogata et al., 2011), and the adaptation to high altitude conditions largely depends on the fitness level (Brugniaux et al., 2006).

One should also note that the literature includes reports which imply lack of expected improvements of physical capacity after applying the LH-TL training model. Hiller et al. (2000) observed strength decrease, fatigue, sleep disturbances, and malaise after a 6-day stay at an altitude of 2000–2500 m a.s.l., 10 hours per day, and execution of training loads at sea level. Therefore, when planning hypoxic training, one should bear in mind individual differences in high-altitude adaptation.

The use of hypoxic tents in sports training is also supported by economic and health-related reasons. It eliminates costs associated with mountain travels and the risk of difficulties in finding accommodation in mountain resorts. It also reduces the probability of diseases resulting from hypothermia or from contacting other people during the journey (Gore et al., 2008; Saunders et al., 2009).

Conclusions

The results of the pilot study provide arguments in the ongoing debate on the validity of applying hypoxic conditions in training periodisation in athletes practising speed disciplines. The changes observed in the study indicate an improvement in anaerobic capacity and blood morphological and biochemical indicators in a sprint running athlete after using a tent simulating high altitude conditions. However, one should emphasise that the LH-TL protocol requires a broad perspective and further research. It seems reasonable to analyse such aspects as diet, training loads implemented at sea level, and the type of rest and regeneration, as well as to establish precise guidelines on the altitude and duration of hypoxia. Still, it is worth noting that the inclusion of hypoxia training in the periodisation of the training process contributed to an improvement in the level of anaerobic capacity, as well as morphological and biochemical blood indicators.

Declaration of interests - The authors declare that there is no conflict of interest regarding the publication of this paper.

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Ethical approval

The study followed the principles of the Declaration of Helsinki and was approved by the Ethics Committee at the Regional Medical Chamber in Krakow, Poland (approval No. 17/KBL/OIL/2015 of February 10, 2016).

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