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FIMS Position Statement

The sleep high – train low concept as performed in altitude simulation facilities

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by

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INTRODUCTION

Since more than 35 years altitude training has been used by endurance athletes in the attempt to augment their competition performance at sea-level. Despite anecdotal reports describing an increased endurance performance after a period of altitude training, the question whether altitude conditions confer an additionally effect to improve endurance performance still awaits scientific clarification (3, 13). Beneficial effects of moderate altitude and in particular of hypoxia are discussed to result primarily from hematological adaptation by increasing total hemoglobin mass and blood volume (14). Beside other factors, hemoglobin mass and blood volume has been shown to be important factors determining aerobic capacity in endurance athletes (7). Furthermore, an improvement of endurance performance by altitude training may result from specific effects of hypoxia on muscle tissue adaptation in response to a given training stimulus (8).

Due to an increasing use of hypoxic apartments or sleeping devices by endurance athletes, the current position stand will focus on the sleep high – train low concept as performed in altitude simulation facilities. It contains information from research that was available through December 2003.

THE SLEEP HIGH – TRAIN LOW CONCEPT

In training practice, exercise intensity has to be reduced at altitude to minimize the risk of overtraining (17). Training adjustment to altitude conditions may negatively affect specific endurance performance especially if altitude training is performed prior a competition period. Thus, an alternative approach to increase exercise performance has been mooted, where training is performed near sea level and the resting and sleeping periods take place at moderate altitude (15, 21). The so-called concept of sleep high – train low, which allows an adequate training intensity, but may augment erythropoesis during acclimatization to the repeated hypoxic periods, has been assumed to be superior to the traditional form of altitude training. A well conducted study (12) in 39 college runners seems to confirm this assumption by showing that hematological acclimatization to natural altitude of 2500 m for 4 weeks and simultaneous training at low altitude (1250 m) improved running time in a 5000 m time trial more than continuous stays and training at altitude (2500 m). In contrast, a shorter protocol of sleep high – train low lasting 2 weeks and performed at a lower altitude of 2000 m was insufficient to augment Hb mass and VO$_2$max in triathletes (5).

SLEEP HIGH – TRAIN LOW IN NORMOBARIC HYPOXIA

In the attempt to make the concept of sleep high – train low more applicable to daily training practice, special techniques have been developed, which allow exposure to normobaric hypoxia at normal altitudes. In hypoxic houses or apartments, normobaric hypoxia is created by lowering the oxygen fraction in the air by either nitrogen dilution or air separation technique. In addition, the use of commercially available altitude tents as hypoxic sleeping devices allows simulation of altitudes up to 4500 m depending on which model is used (24).

Exposure to normobaric hypoxia using such locations typically lasts up to 16 hours a day in hypoxic apartments and up to 8 – 10 hours a day in hypoxic tents. In parallel, the training program can be realized in a habitual environment in normoxia. Scientific evaluation of the sleep high – train low concept in normobaric hypoxia (Table 1) in studies conducted in Finland initially suggested an augmenting effect on red cell volume (11, 22) and VO$_2$max (22). In contrast, a study of the same group revealed no additional effect of normobaric hypoxia on red blood cell volume of cross-country skiers (19). Research in Australian endurance athletes failed to detect a significant effect of sleep high – train low in normobaric hypoxia on reticulocyte counts and hemoglobin mass (1, 2). Importantly, daily exposure to hypoxia was shorter in the latter two experiments, when compared to the Finnish studies. This points to a threshold for the daily duration and extent of hypoxic exposure, which has to be exceeded to induce measurable effects on hemoglobin mass or red cell volume, respectively. However, definition of such a threshold appears difficult as erythropoietin response to hypoxia and resulting increase of red cell volume shows large individual variability (4). Furthermore, methodological aspects and in particular the different detection methods of Hb mass and RCV (Evans blue dye technique, CO rebreathing technique, ^{99}Tc labelling method) may also account in part for the divergent findings in the studies mentioned above (1, 24).

Although limited, initial research suggest that potential effects of sleep high – train low in altitude simulation facilities are not restricted to the hematopoetic system, but may also exert improving effects on anaerobic performance with significant reduction of running time for 400 m (18) and an increase of muscle buffer capacity (6). Furthermore, maximal accumulated oxygen deficit during incremental cycling exercise until exhaustion has been shown to be enhanced after sleep high – train low over a period up to 15 days (20). These preliminary findings need further evaluation in controlled double blind trials.

Recent reports from a well-controlled trial indicate that 4 weeks of 5 : 5 min intermittent hypoxia exposures (corresponding to an altitude up to 6000m) for 70 min lasting 3 hours per day have no effect on VO_2max, performance during a 3000 m time trial and erythropoesis (9).

SIDE EFFECTS AND SAFETY ASPECTS

Shannon et al. (23) evaluated possible side effects of 8 hours resting and sleeping at a lowered oxygen fraction of 15.3% (corresponding to an altitude of approx. 2500 m) in an altitude tent for 5 consecutive days. As expected, they observed no symptoms associated with acute mountain sickness (AMS). However, they detected an increase of air CO_2, which stabilized at a tolerable level of 0.6±0.15%. Furthermore, they found an increase of the relative humidity to relatively high values of 88% in average, a finding which may lower sleeping comfort in such small sleeping devices. If lower oxygen fractions are used (e.g. corresponding to an altitude of approx. 4000 m), symptoms of AMS may occur during the first few exposures over night or periods ≥ 6 hours during the day (10). Thus, a lower extent of hypoxia is recommended in the first days of a sleep high – train low period to allow acclimatization without symptoms of AMS. Anecdotal reports reflect, that personal experiences of athletes regarding the practicability of the use of hypoxic apartments or sleeping devices during daily training practice considerably vary. Standardized evaluations of the question in which extent repeated stays in hypoxic devices interfere with the over-all quality of life are not available at yet. This seems to be of special interest as cognitive and emotional factors may also influence athlete's performance. Also, it remains to be determined, whether repeated exposure to normobaric hypoxia acts as an additional stress factor, e.g. for the immune system. Initial results revealed a decrease of phagocytic capacity within the normal range and an unchanged oxidative burst in neutrophils and monocytes obtained from humans after acute exposure to 23 h of normobaric hypoxia (F_iO_2 13.8%, approx. 3200 m) in a hypoxic chamber (16). These results did not strengthen the assumption that exposure to normobaric hypoxia as performed in the practice of sleep high – train low goes along with a relevant impairment in host defence. On the other hand, it has to be taken into account that slight suppressive effects of hypoxia on immunosurveillance may become relevant in context with additional physical stress or may be enhanced during repeated hypoxic sessions.

With regard to safety aspects, it is recommended that hypoxic sleeping devices should only be used in connection with a continuous monitoring of room air oxygen- and CO_2 - concentrations.

CONCLUSIONS AND PERSPECTIVES

(1) Current data suggest that exposure times of 16 hours and more per day at oxygen fractions corresponding to an altitude of ≥2500 m are needed to increase Hb mass and aerobic performance in endurance trained athletes. However, large individual variability of the erythropoetic response to hypoxia does not allow precise recommendations regarding this threshold effect. Whether shorter but more severe hypoxia is effective is currently not known. In this context, it has taken into account that such protocols may exert negative side effects such as symptoms of AMS or disturbances in immune function.

(2) Shorter protocols (8-10 hours/d) may increase anaerobic power, but additional research addressing this issue is necessary and should also focus on effects on substrate utilization.

(3) Very short (≤ 3 hours/d) and intermittent exposures to normobaric hypoxia using oxygen fractions corresponding to an altitude up to 6000 m do not stimulate erythropoesis or improve VO_2max and performance.

(4) More compelling evidence regarding the compatibility of altitude simulation facilities in daily training practice is needed.

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Table 1: Summary of available athlete studies with normoxic control groups evaluating the effect of sleep high – train low in hypoxic apartments on Hb mass or red cell volume

Athletes	Simulated altitude	Exposure Protocol	Δ RCV	Δ Hb$_m$	Detection method	Reference
Runners n=7 (H), n=7 (C)	2500 m	16 - 18 h / d (20-28 d)	H: + 7% * C: →		EB	11
Endurance, mixed n=12 (H), n=10 (C)	2500 m	12 - 16 h / d (25 d)	H: + 5.0% * C: →		EB	21
Cross-country skiers n=7 (H), n=7 (C)	2500 m	12 - 16 h / d (25 d)	H: +7.9% * C: +4.8% *		Tc	19
Endurance, mixed n=6 (H), n=7 (C)	3000 m	8 – 10 h / d (23 d)		H: → C: →	CO	1
Female cyclists n=6 (H), n=6 (C)	2650 m	8 - 10 h / d (12 d)		H: → C: →	CO	2

H: hypoxic group, C: control group, Hb$_m$: hemoglobin mass, RCV: red cell volume, EB: Evans blue dye method, Tc:^{99}Tc labelling method, CO: carbon monoxide rebreathing method; → no significant change; * reflects significant change compared to pre-exposure value.