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Body Composition and Aerobic Performance Changes After 8 Weeks of Exposure to Normobaric Intermittent Hypoxia

Cambios en la Composición Corporal y el Rendimiento Aeróbico Después de 8 Semanas de Exposición a Hipoxia Normobárica Intermitente

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SUMMARY: To take advantage of altitude, "intermittent hypoxia" methods have been developed that involve shorter exposures to hypoxia. In general, systemic hypoxia can be produced in two ways: (1) by lowering barometric pressure (BP, hypobaric hypoxia) or (2) by reducing the amount of oxygen in inspired air (FiO2) through oxygen filtration or nitrogen dilution (normobaric hypoxia). The objective of this analysis was to observe changes in body composition and aerobic performance after 8 weeks of intermittent hypoxia exposure at rest. A total of 20 male volunteers between the ages of 18-26 participated in the study. Participants were randomly divided into 2 groups (Control Group and Intermittent Hypoxia Group). The Intermittent Hypoxia Group completed the process by being exposed to intermittent hypoxia for 8 weeks. Each intermittent hypoxia session was planned as 3 days a week and for 1 hour. After 8 weeks of experimental process, statistically significant differences were found for lean mass, android lean mass, gynoid lean mass, the relative skeletal muscle mass index, peak lactate, 1mmol lactate threshold, 4mmol lactate threshold, and MaxVo2 variables (p<0,05). After 8 weeks of intermittent hypoxia exposure, an increase in maximal oxygen consumption capacity was observed. The increase in lean mass, especially in the gynoid and android regions, can be explained by the increase in fat burning activities due to oxygen utilization capacity. Almost every study reviewed in the literature used different intermittent hypoxia exposure protocols and different simulated altitudes. The method discussed in this study may be beneficial on the body composition and oxygen utilization capacity of sedentary individuals.

KEY WORDS: Hypoxia; Altitude; Body Composition; Oxygen Consumption.

INTRODUCTION

The use of intermittent hypoxia at rest has not improved the performance of elite athletes at sea level. However, it can be used for pre-acclimatisation before travelling to high altitudes (Burtscher *et al*., 2022). However, when sedentary individuals use intermittent hypoxia at rest or in combination with exercise, positive effects on health-related characteristics such as cognitive function, vascular function and glucose homeostasis have been observed (Luo *et al*., 2022). In addition to these conditions, the use of intermittent hypoxia at rest has beneficial effects on cardiovascular, metabolic and neurodegenerative disorders, as well as on overweight and obese individuals (Camacho-Cardenosa *et al*., 2019a). Intermittent hypoxia at rest has been a topic of interest in understanding its potential effects on body composition and bone mineral density. The influence of intermittent hypoxia on bone metabolism and mineral density has been a subject of investigation, with contradictory findings in the literature (Camacho-Cardenosa *et al*., 2019b). While some studies have suggested potential alterations in bone remodeling and mineral density due to hypoxia, others have reported no significant effects on bone structure or density (Rittweger *et al*., 2016; McDonnell *et al*., 2019).

From this point of view, the aim of the current study was to observe 8-week intermittent hypoxia exposure at rest in sedentary subjects 1.body composition, and 2. aerobic performance changes.

MATERIAL AND METHOD

Participants: The study included a total of 20 male volunteer participants, ages 18 to 26, who were students at the Anadolu University Faculty of Sports Science. They

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were free from health issues that would have prevented them from taking part in the study and did not play any active sports that would have interfered with the testing procedure. The study has been approved by the Clinical Research Ethics Committee of Osmangazi University Faculty of Medicine (Protocol No:80558721/65). The volunteer participants were given verbal explanations of each stage of the study prior to its execution, and they provided signed informed consent. The volunteers were randomly assigned to the control group (CG, n=10, body weight: 69.844±7.50 kg; height: 1.73±0.7 m; age: 22.4±2.8 years) and the Intermittent Hypoxia Group (IHG, n=10, body weight: 72.738±8.930 kg; height: 1.70±0.14 m; age: 21.2±1.4 years) after the pre-tests and formed the research groups.

Measuring Bone Mineral Density. To calculate the bone mineral density of people with different energy levels, double X-rays were taken.

Analyses of the Lactate Samples. The blood lactate marker calculation software was used to calculate the watt and heart rate data at 1 mmol and 4 mmol lactate (Newell *et al*., 2007).

Maximal Oxygen Consumption and Lactate Levels Were Determined During the Incremental Cycling Protocol. The point at which CO2 consumption is higher than O_2 consumption was determined to be the transition to anaerobic metabolism (Murias *et al*., 2010). Workload (watts), heart rate and lactate levels (4 mmol) at this point were recorded separately. The average oxygen consumption achieved in the last 30 seconds of the test was considered the maximal oxygen consumption. It was assumed that the RER of the volunteers was 1.10 and above, and the maximum oxygen consumption value was reached when the maximum heart rate was ± 5 beats.min-1 (Carter *et al*., 2000).

Intermittent Hypoxia Exposure at Rest. Intermittent hypoxia sessions were scheduled on Friday, Saturday and Sunday. It has been reported that it is important to undergo an acclimatisation process in simulated altitude chambers before climbing high mountains to avoid acute altitude sickness (Küpper & Schoeffl, 2012). The literature also mentions that acclimatisation studies can be conducted for 1 hour and up to 4 weeks daily without climbing high mountains (Burtscher *et al*., 2007). With this in mind, the first 6 sessions of the IHG. were set as acclimatisation and the altitude was increased in each session. After the acclimatisation phase, the remaining 18 sessions were set at 3000m (~ 14.3 % O_2).

Statistical Evaluations. A mixed design anova was used to observe differences between time and group. The significance level was taken as $p<0.05$.

RESULTS

At the end of the 8-week period of intermittent hypoxia exposure, changes in body composition are given in Table I and changes in aerobic performance are given in Table II.

Table I. Body composition changes.

Parameters	Control Group Pre Test χ ± (n=10)	Control Group Post Test χ ± (n=10)	Intermittent Hypoxia Group Pre Test χ ± (n=10)	Intermittent Hypoxia Group Post Test χ ± (n=10)	p Time x Group Effect *p*
Total Mass (kg)	64,577±7,559	64,844±7,50	72,738±8,930	73,445±9,846	0,473
Lean Mass (kg)	49,274±5,122	49,481±4,881	55,770±5,462	56,724±6,084	0,015*
Fat Mass (kg)	12,517±3,583	12,555±3,621	13,960±4,156	13,706±4,382	0,409
Android Mass (kg)	4,300±0,800	4,266±0,739	4,728±0,608	4,803±0,707	0,165
Android Lean Mass (kg)	3,464±0,470	3,432±0,344	3,785±0,425	3,869±0,479	0,044*
Android Fat (g)	482,862±324,784	473,205±306,885	498,820±409,514	469,074±378,091	0,897
Gynoid Mass (kg)	17,811±6,147	17,811±6,177	18,522±4,241	18,155±4,594	0,993
Gynoid Lean Mass (kg)	10,511±1,367	10,577±1,402	11,902±1,869	11,948±2,095	0,013*
Gynoid Fat (kg)	7,989±0,881	8,019±0,893	9,307±1,137	9,409±1,196	0,272
Gynoid Fat (%)	2,237±0,812	2,259±0,789	2,287±0,928	2,228±1,037	0,334
Android/Gynoid Ratio	21,477±6,240	21,611±5,730	19,255±5,211	18,511±5,577	0,102
Body Mass Index (kg/m^2)	21,488±1,883	21,422±1,787	23,932±3,006	23,933±3,006	0,325
Resting Metabolic Rate (cal)	1644,55±138,178	1640,33±135,161	1783,77±127,069	1782,66±126,941	0,331
The Relative Skeletal Muscle Mass Index (kg/m^2)	7,605±0,780	7,611±0,753	8,465±1,017	8,597±1,109	0,050*

*p<0,05

Table II. Aerobic performance changes.

Parameters	Control Group		Intermittent Hypoxia Group		p
	Pre Test $\chi \pm$ (n=10)	Post Test $\chi \pm$ (n=10)	Pre Test $\chi \pm$ (n=10)	Post Test $\chi \pm$ (n=10)	Time x Group Effect *p*
Test Duration (s)	815,18±107,70	811,75±100,48	865,7±153,46	889,6±157,76	0,075
Maximum Watt	262,5±34,92	260±30,98	282±49,39	288±48,25	0,078
Peak Lactate (mmol)	8,91±1,69	8,55±1,41	10,05±1,97	10,30±1,98	0,000**
Maximum BPM	183±5,93	183,06±4,37	184,8±4,63	186,1±5,19	0,292
1 mmol Lactate Threshold (watt)	109,08±10,29	108,01±10,23	111,42±10,01	116,30±8,04	0,000**
1 mmol Lactate Threshold (BPM)	121,78±8,45	121±8,19	124,12±5,47	122,62±6,39	0,330
4 mmol Lactate Threshold (watt)	163,61±11,29	162,09±10,46	172,41±8,5	177,01±8,6	0,000**
4 mmol Lactate Threshold (BPM)	164,35±8,14	164,09±8,51	167,03±6,59	168,42±6,39	0,069
MaxVo$_2$ (ml.kg^{-1}.min)	34,78±3,43	34,61±3,34	37,84±5,18	40,10±4,99	0,000**

*p<0,05; **p<0,01; BPM: Beat per minute.

DISCUSSION

In this study, it shows that the MaxVO2 value of IHG increased by 2.26 ml.kg-1.min. MaxVO2 consumption of CG decreased by 0.17 ml.kg-1.min. In percentage terms, MaxVO2 increased by 5.97 % for IHG and decreased by 0.48 % for CG. These results support the hypothesis in the literature that the "ability to utilise oxygen" increases (Sinex & Chapman, 2015). Beidleman *et al*. (2009) found that to improve performance at sea level, staying in this environment for about 3 hours per day for a period of 1-3 weeks at a simulated altitude of 3000 m improved aerobic performance in particular. Our results for MaxVO2 support this argument. In contrast, Wood *et al*. (2006) conducted hypoxia exposure sessions at 3600 m for 15 days. Each session lasted 60 min, and after 6 min of hypoxia exposure, they were exposed to normal ambient air for 4 min. Only the sprint times and resting heart rates of the male field hockey and soccer players improved during this trial. In contrast, Tadibi *et al*. (2007) and Wood *et al*. (2006) applied the same hypoxia exposure protocol to 20 male participants who were engaged in endurance training. They did not find any improvement in MaxVO2 in their study. Lundby *et al*. (2005) performed a 2-h hypoxia exposure at an altitude of approximately 4300 m for 14 days. Eight trained men participated in their study. As a result, they could not detect any change in MaxVO2 value in both the maximal and submaximal ranges. Katayama *et al*. (2004) included 15 middle distance runners in their study. The 3-hour hypoxia exposure protocol, which lasted 14 days, took place at an altitude of approximately 3200m and they were found no change in aerobic metabolic parameters (heart rate, MaxVO2, RER). In the study by Maher & Figueroa (2016), an altitude mask simulating an altitude of approximately 2750 meters was used. Although there was an increase in MaxVO2 values of college students who performed cycling between 55-65 % of their maximum heart rate for 6 weeks and 15 minutes twice a week, this increase was not statistically significant.

As can be seen in the above studies, the same hypoxia protocol was almost never used. The experimental groups also show no similarity. None of the male volunteers aged 18 to 26 years who participated as the subject group in our study is a competitive athlete. In most studies with elite athletes, no improvement was observed. The goal of intermittent hypoxia is to enhance performance at sea level by providing physiologically appropriate stimuli. The MaxVO2 of elite athletes does not increase with intermittent normobaric hypoxia (Julian *et al*., 2004). The main reason for the increase observed in this study may be that the volunteer participants were not elite (Bonetti & Hopkins, 2009).

Some studies attribute the evolution of MaxVO2 value by about 1-5 % to the evolution of hemogram parameters (Stray-Gundersen *et al*., 2001). However, there are MaxVO2 values in the literature that increase without any change in hemogram parameters (Hendriksen & Meeuwsen, 2003; Vogt & Hoppeler, 2010). In those studies found 7 % and 1.9 % increase in MaxVO2 levels, respectively, but found no improvement in hemogram parameters. One of the possible reasons for this increase could be HIF-1 (hypoxia-induced factor-1). HIF-1 plays a crucial role in cardiovascular responses. Thanks to the activation of HIF-1, vascular regulation changed and the increased blood circulation was able to supply more oxygen to the active muscles (Vogt & Hoppeler, 2010). On the other hand, found that not everyone can respond to the hypoxic environment to the same degree, so no change in the tested parameters could be seen. Exposure to hypoxia does affect performance in some way, but even though that live-at-low is necessary to enhance performance of elite athletes at sea level, it is not guaranteed to enhance performance of elite athletes at sea level (Faiss *et al*., 2013)

Changes in incremental cycle protocol after intermittent Hypoxia Exposure. In this study, the performance criteria examined were maximal test time (exhaustion time) and maximal wattage (power) obtained from the incremental cycling protocol. Although the total test time for IHG increased from 865.7 s to 889.6 s after the hypoxia exposure protocol, this result was not statistically significant. The total test time of CG decreased from 815.18 s to 811.75 s. While the maximum wattage increased from 282 to 288 watts for IHG, it decreased from 262.5 to 260 watts for CG.

The increase in wattages corresponding to the lactate thresholds of the volunteer participants in our study could be due to training economy. Nakamoto *et al*. (2016) stated in their study that the factor for improvement in lactate levels was related to running economy. All groups achieved the same speeds at lower lactate levels during running. Since the protocol we used for our research is the bicycle ergometer, it would be more accurate to evaluate this situation with pedal economy (bicycle). Running economy can only be improved by running exercises. However, pedal economy does not require pedal-based exercises to develop. Pedal economy can also improve independently (Swinnen *et al*., 2018). The constant lactate-to-watt increase in pedal economy observed in our study may be related to this.

Body Composition Changes. After the hypoxia protocol applied to IHG, there was a 1.71 % increase in lean mass, a 2.21 % increase in android lean mass, and a 0.40 % increase in gynoid lean mass ($p<0.05$). No statistically significant increase in these values was observed for CG. The Relative Skeletal Muscle Mass Index (RSMI) value increased by 1.56 % for IHG. For CG, this value did not change.

Some recent studies in the literature have reported that exposure to intermittent hypoxia increases fat burning, improves cardiovascular health parameters, and reduces cardio-metabolic risk factors, along with an increase in the ability to use oxygen (Hobbins *et al*., 2017).

Chia (2013) conducted their study of 2300 meters with 8 elite swimmers in 3 weeks. As a result of the study, they found that the total fat mass of the swimmers decreased by 11.4 % and their total lean mass increased by 1.5 %. Guner *et al*. (2013) studied the effects of intermittent hypoxia on bone density in mice. They mentioned that chronic hypoxia can have positive effects on bone density, using the protocol they applied in a hypobaric room at an altitude of about 4600 meters, for 5 weeks, 5 days/weeks, 5 hours/days. Although most studies on this topic refer to animal experiments, the metabolic processes are similar (Argilés *et al*., 2004). Oxygen is the final acceptor of the electron transfer system in the oxidation of fats. Although there is less oxygen at altitude, the degree of oxidation of oils is higher. This result is due to the fact that skeletal muscles are more stressed. Chia (2013) found that insulin activity along with increased hemoglobin delivered more energy to skeletal muscle. Increased energy (Hamad & Travis, 2006). These comments argue for a decrease in IHG in adipose tissue.

CONCLUSION

The study's findings led to an evaluation of the changes performed to the 8-week intermittent hypoxia exposure protocol in terms of physiological, performance, and body composition characteristics. The densitometry values of the investigated parameters did not change.

Maximum oxygen consumption capacity increased following exposure to intermittent hypoxia. The rise in lean mass, particularly in the gynoid and android regions, demonstrated that oxygen consumption ability and fat burning activity were both improved by intermittent hypoxia. It is clear from a review of the literature that nearly all procedures for intermittent hypoxia utilise various simulated altitudes and durations. Consequently, it was determined that the study's protocol should be put into practice, particularly sedentary persons.

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RESUMEN: Para aprovechar la altitud, se han desarrollado métodos de «hipoxia intermitente» que implican exposiciones más cortas a la hipoxia. En general, la hipoxia sistémica se puede producir de dos maneras: (1) reduciendo la presión barométrica (PA, hipoxia hipobárica) o (2) reduciendo la cantidad de oxígeno en el aire inspirado (FiO_2) mediante filtración de oxígeno o dilución de nitrógeno (hipoxia normobárica). El objetivo de este análisis fue observar cambios en la composición corporal y el rendimiento aeróbico después de 8 semanas de exposición intermitente a hipoxia en reposo. Participaron en el estudio un total de 20 voluntarios varones de entre 18 y 26 años. Los participantes se dividieron aleatoriamente en 2 grupos (grupo control y grupo hipoxia intermitente). El grupo de hipoxia intermitente completó el proceso al estar expuesto a hipoxia intermitente durante 8 semanas. Cada sesión de hipoxia intermitente se planificó 3 días a la semana y durante 1 hora. Después de 8 semanas de proceso experimental, se encontraron diferencias estadísticamente significativas para la masa magra, la masa magra androide, la masa magra ginoide, el índice de masa muscular esquelético relativo, el pico de lactato, el umbral de lactato de 1 mmol, el umbral de lactato de 4 mmol y las variables $MaxVo_2$ ($p< 0,05$). Después de 8 semanas de exposición intermitente a hipoxia, se observó un aumento en la capacidad máxima de consumo de oxígeno. El aumento de la masa magra, especialmente en las regiones ginoidea y androide, puede explicarse por el aumento de las actividades de quema de grasa debido a la capacidad de utilización de oxígeno. Casi todos los estudios revisados en la literatura utilizaron diferentes protocolos de exposición intermitente a la hipoxia y diferentes altitudes simuladas. El método analizado en este estudio puede ser beneficioso para la composición corporal y la capacidad de utilización de oxígeno de personas sedentarias.

PALABRAS CLAVE: Hipoxia; Altitud; Composición corporal; Consumo de oxígeno.

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