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THE EFFECTS OF SHORT-TERM HYPOXIA ON UPPER BODY ISOMETRIC STRENGTH AND REACTION TIME

UČINCI KRATKOTRAJNOG BORAVKA U HIPOKSIJI NA JAKOST GORNJIH EKSTREMITETA I VRIJEME REAKCIJE

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SUMMARY

Since the 1968 Olympic Games in Mexico, hypoxic training became popular, especially among long-distance runners. In the many years since, studies have shown that many types of hypoxic training can not only improve aerobic capacity and performance, but also have the potential for other positive adaptations such as hypertrophy, metabolism, and many others. Most studies dealt with a long-term training program under hypoxic conditions, and there is a lack of studies on acute hypoxia effects. This study aims to investigate the effects of short-term normobaric hypoxia (2800m; FiO2: 14.5%) on upper body isometric strength and reaction time in male volunteers.

Twelve healthy male volunteers (mean age 34.72 ± 7.43 years) participated in the study. Over 48 hours, they underwent normobaric hypoxia and sleep at least two times per 12 hours. The protocol included motor tests in three phases: 48 hours before departure, the morning of departure, and immediately after the hypoxic stay. The four motor tests were measured in the morning (always at the same time): Isometric Forearm Flexion,) Handgrip Strength of the dominant hand, Ruler Drop Test and Flamingo balance test. The results showed a significantly lower score for isometric forearm flexion ($p = 0,039$) while handgrip strength the Handgrip Strength, and ruler drop test show no significant changes ($p = 0,223$; $p = 0,143$). The balance test proved to be too easy. Based on the results, we can conclude that short-term hypoxia might negatively affect isometric strength of the forearm flexors immediately after the exposure.

Keywords: hypoxia, normobaric hypoxia, strength, reaction time

SAŽETAK

Od Olimpijskih igara 1968. u Meksiku, hipoksični trening postao je vrlo popularan, posebno među trkačima na duge staze. U godinama koje su uslijedile, studije su pokazale da mnoge vrste hipoksičnog treninga ne samo da mogu poboljšati aerobni kapacitet i izvedbu, već također imaju potencijal za druge pozitivne prilagodbe kao što su hipertrofija, poboljšanje metabolizmam i sl. Većina studija do sada proučavala je dugotrajne programe treninga u hipoksičnim uvjetima, a nedostaju studije o učincima akutne hipoksije. Ova studija imala je za cilj istražiti učinke kratkotrajne normobarične hipoksije (2800m; FiO2:14,5%) na izometričku jakost gornjeg dijela tijela i vrijeme reakcije u muških dobrovoljaca.

U istraživanju je sudjelovalo dvanaest zdravih muških dobrovoljaca (prosječne dobi 34,72±43 godine). Tijekom vikend boravka od 48 sati bili su podvrgnuti normobaričnoj hipoksiji 2 puta po 12 sati. Protokol je uključivao motoričke testove u tri faze: 48 sati prije polaska, ujutro polaska i neposredno nakon hipoksičnog boravka i tim dizajnom su služili ka kontrolna grupa sami sebi (dva mjerenja bez intervencije). Četiri motorička testa mjerena su ujutro (uvijek u isto vrijeme): izometrička jakost fleksije podlaktica, jakost dominantne šake i test reakcije tj. hvatanja padajućega ravnala. Rezultati pokazuju značajno niži rezultat za izometrijsku fleksiju podlaktice ($p = 0,039$), snagu hvata za snagu rukohvata i test pada ravnala ne pokazuju značajne promjene ($p = 0,223$; $p = 0,143$).

Na temelju rezultata možemo zaključiti da kratkotrajna hipoksija negativno utječe na izometrijsku snagu fleksora podlaktice.

Ključne riječi: hipoksija, normobarična hipoksija, jakost, vrijeme reakcije

INTRODUCTION

Since the beginning of modern sports and competition, every day becomes a struggle to find new, better, and more effective ways to improve athletes' performance. The idea of high altitude (hypoxic) training is not new, but its usage in training become popular around the 1968 Olympic Games, among athletes involved in endurance type of sports (6). There are many principles of training in hypoxic conditions such as Live low-Train high (the most popular), Live high -Train low, Live high-Train high, etc. (9). The plethora of evidence shows the benefits of hypoxic training are not only for aerobic capacities, actually many hypoxic training principles can improve the other aspects of motor, and physiological functions. The studies show that this type of training can affect adaptations like hypertrophy (12), which is induced by increased metabolic stress (13). The buildup of metabolites (11) raises plasma growth hormone (14) and muscle cell swelling, which might be to increase muscle protein synthesis (7). A variety of studies investigate the effects of hypoxia conditions, but most of them relate to long-term exercise and training under these conditions. There is a lack of studies that investigate the effects of acute, short-term hypoxia on motor parameters. A few conducted studies show that acute hypoxia has a decreasing effect on those parameters. In the study by Karayigit et al. (4) decreasing effect of moderate (3000m; the fraction of inspired oxygen (F_iO_2): 14%) and high (4000m; F_iO_2: 12%) doses of acute hypoxia was noticed in upper body muscular endurance and cognitive tasks. Ramos-Campo et al. (10) found comparable results. Lei et al. (5) found that short-term hypoxia can lead to an improvement in reaction time in female subjects. Therefore, the goal of this study was to examine the effects of short-term normobaric hypoxia (2800m; F_iO_2: 14.5%) on upper body isometric strength and reaction time in male subjects.

Study design

A within-subjects design was used in this experimental research. The purpose of this study was to determine how short-term normobaric hypoxia affects simple motor tasks. Pre/post scores with no intervention were compared to pre/post scores of the same subject under intervention conditions to control the effects. In the no intervention vs. intervention conditions, each participant served as their own control.

Subjects and Methods

Twelve healthy male volunteers (mean age 34.72 ± 7.43y) took part in the study. They were managers or had extremely demanding occupations that needed several customer or coworker interactions and conversations each day. They were in good health, with no known chronic conditions that would require them to take medication. Mean body mass index of the subjects was 25,27±2,60 kg/m^2 with the highest being 28,73 kg/m^2 but none of them were obese.

Over the course of 48 hours at least 2 times per 12h, they were treated to stay and sleep in normobaric hypoxia (designed to simulate oxygen levels at about 2800m, F_iO_2 ≈ 14.5%). The intention was to develop conditions for the weekend meetings' hypoxia stays.

The protocol involved motoric testing in three stages: 48h before the departure (Wednesday), on the morning of departure (Friday), and immediately after hypoxic stay (Sunday morning at the location of the intervention, immediately after the hypoxia stay). The 4 motoric tests that were measured at the same time each morning: (i) Isometric Forearm Flexion, (ii) Handgrip Strength of the dominant hand, and (iii) Ruler Drop Test and (iiii) Flamingo balance test.

A 12- to 13-hour stay/sleep in hypoxia in one of the ten rooms (20 beds) with the possibility of simulating an altitude of up to 6000 meters was simulated in the Planica Nordic Center of the Hotel Dom Planica. The altitude of 2800 m was chosen for this study based on the demographics of our subjects and following the purpose of the study.

RESULTS

A descriptive statistic of the scores is represented in Table 1. The results showed significant post-intervention differences in only one of the observed tests. The subjects have significantly lower scores in post-intervention testing in Isometric Forearm Flexion ($p = 0.039$) (Figure 1). Figures represent ANOVA for repeated measures and post hoc Fisher test results.

After the intervention, no significant changes had occurred in Handgrip strength, even if we can see decreasing in the managed score ($p = 0,233$) (Fig 2).

The Ruler Drop Test (reaction time) showed some decrease in the score, in this case, it means improving the time of reaction (faster reaction, lower score on ruler), but with no statistically significant changes ($p = 0,143$) (Fig 3).

Table 1. Desrriptive data for all variables
Tablica 1. Desriptivni podaci za mjerene varijable

Variables	Descriptive Statistics			
	Mean	Minimum	Maximum	Std.Dev.
Isometric Forearm Flex before 1 (kg)	140,67	101,00	270,00	51,23
Isometric Forearm Flex before 2 (kg)	145,00	100,00	270,00	50,69
Isometric Forearm Flex after	119,33	12,00	200,00	45,06
Handgrip before 1 (kg)	39,83	24,00	118,00	25,41
Handgrip before 2 (kg)	33,25	24,00	47,00	6,62
Handgrip after	30,33	20,00	42,00	6,69
Ruler Drop Test before 1 (cm)	23,98	20,00	35,40	4,60
Ruler Drop Test before 2 (cm)	22,08	16,60	27,40	2,99
Ruler Drop Test after	20,63	15,00	29,40	4,06
	median			Conf . int. ‘95%
Flamingo balance test before 1* (N)	0	0	0	0,00
Flamingo balance test before 2* (N)	0	0	4	0,84
Flamingo balance test after*	0	0	2	0,56

**Flamingo balance test was later found not to be appropriate for the subjects which were quite able-bodied*

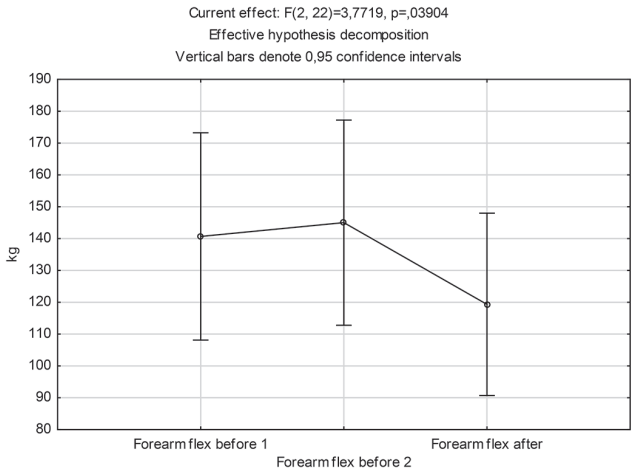

Figure 1. The results of the ANOVA for repeated measures showing significant drop in forearm flexors strength immediately after intervention

Slika 1. Rezultati ANOVE za ponavljajuća mjerenja ukazuju u značajni pad jakosti fleksora podlaktice neposredno nakon intervencije

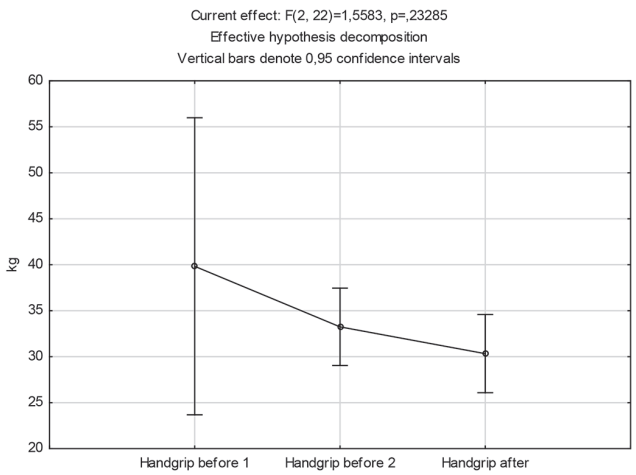

Figure 2. The results of the ANOVA for repeated measures showing no statistically significant changes after intervention in hangrip strength

Slika 2. Rezultati ANOVE za ponavljajuća mjerenja ne ukazuju na značajni pad jakosti šake nakon intervencije

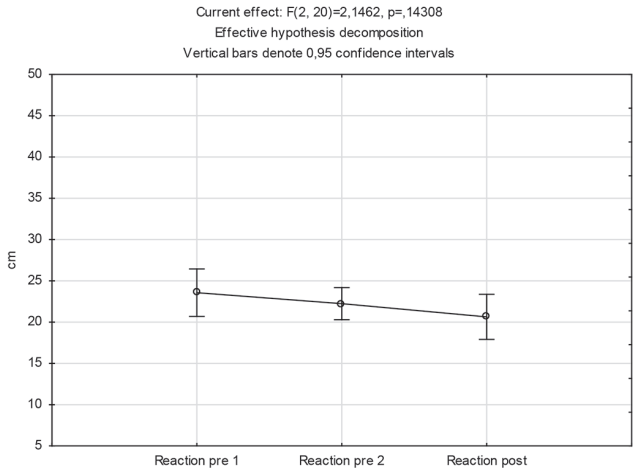

Figure 3. The results of the ANOVA for repeated measures showing no statistically significant changes after intervention in reaction time (e.g. centimeters on ruler drop test)

Slika 3. Rezultati ANOVE za ponavljajuća mjerenja ne ukazuju na značajne promjene u vremenu reakcije nakon intervencije (tj. centimetara na testu ravnala)

The results of the forth motor test, Flamingo balance test, will not be discussed in detail as the results showed no variance. All subjects but one performed the test with the best score in all three measurements so it was probably too simple for the ability of the subjects to elicit any significant effects.

DISCUSSION

Short-term exposure to hypoxia may negatively impact motor skills if measured immediately after the intervention. As we can see from obtained results there was a decreasing trend in scores of both isometric tests. The significant change in the Isometric Forearm Flex test and nonsignificant changes in Handgrip strength may be associated with reduced arterial and muscular oxygenation, electromyographic activity (13), and neuromuscular activation (1). Slight, but no significant improvement was shown in reactive time on the Ruler Drop test. It was not surprising as it was proven before. As mentioned in in introduction, the short-term hypoxia can lead to an improvement in reaction time in females (5). This small improvement in reaction time score may be associated with practice effects (2). To reduce practice effects to the minimum, subjects did the familiarization with the test, before the baseline measuring (10 tries before baseline measuring). The non-significant change in reactive time in males compared to the study by Lei et al (5), can be explained due to the females being more resilient to hypoxic conditions than men (8). The downside of this study was the low number of participants and it was conducted on male subjects only.

In conclusion and based on the achieved results we can conclude that short-term hypoxia at 2800m altitude and F_iO_2 14.5% negatively affect the isometric strength of the forearm flexors, at least immediately after exposure. A decrease in isometric strength may be explained by the physiological response of the body in hypoxic conditions. In case a coach plans an exposure to hypoxia in top level athlets the training program after the hypoxia should probably be adjusted or at least this fact taken into the consideration. The biggest limitations of this study are two: one is that no follow up measuremets (like a day after exposure) were executed and the second one is the problem of too simple balance test for ths subjects which led to no conclusions.

Future studies should examine how different levels of acute hypoxia affects motor skills in a larger number of participants both male and female.

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