Journal of Trace Elements in Medicine and Biology 45 (2018) 136–141

Contents lists available at ScienceDirect

Journal of Trace Elements in Medicine and Biology

journal homepage: www.elsevier.com/locate/jtemb

Toxicology

# Effect of long-term aerobic, anaerobic and aerobic-anaerobic physical training in seric toxic minerals concentrations[☆]

Marcos Maynar-Mariño[a,*], Francisco Llerena[b], Ignacio Bartolomé[a], Carmen Crespo[a], Diego Muñoz[c], María-Concepción Robles[c], María-Jesús Caballero[b]

[a] *Department of Physiology, School of Sport Sciences, University of Extremadura, University Avenue, Cáceres, Cáceres, 0071, Spain*
[b] *Department of Medical-Surgical Therapeutics, School of Medicine, University of Extremadura, Elvas Avenue, Badajoz, Badajoz, 06071, Spain*
[c] *Department of Medical-Surgical Therapeutics, School of Medicine, University of Extremadura, Elvas Avenue, Badajoz, Badajoz, 06071, Spain*

ARTICLE INFO

*Keywords:*
Toxicity
Toxic minerals
Training
Serum
Performance
Energetic metabolism

ABSTRACT

*Background:* Many substances poured out from industries can be toxic to humans and can impair physical performance. Besides, physical training may modify the body concentrations of these substances as a result of physiological adaptations.
*Objectives:* The aim of the study was to determine if different modalities of exercise might affect serum concentrations of toxic trace elements in sportsmen.
*Methods:* 80 Spanish national sportsmen were recruited before the start of their training period. All the athletes had been training regularly for the previous two years with a rigorous training target at high-level competition. 31 sedentary participants from the same geographic area formed the control group. Serum arsenic, beryllium, cadmium, cesium and lead samples were analyzed with an ICP-MS.
*Results:* Serum concentrations were higher among the sportsmen group than among the control group, being highly significant in cases of Be from 0.043 ± 0.019 to 0.074 ± 0.029 μg/L, Cs from 0.693 ± 0.305 to 1.358 ± 0.569 μg/L and Pb from 0.162 ± 0.171 to 2.375 ± 1.699 μg/L; and significant in the case of Cd from 0.046 ± 0.027 to 0.067 ± 0.059 μg/L. However, if they were separated according to different sport modalities, it was found that, although they had higher concentrations than controls, there were elements that changed their concentrations in relation to the metabolic type of activity performed.
*Conclusions:* In some cases physical exercise induces favorable adaptations to avoid environmental pollution damage. Endurance training (65–75% $VO_{2max}$) can be considered the most effective exercise to prevent toxicity effects. However, integral-matrixes analysis are required in further research to overcome some controversial behaviors of some elements.

## 1. Introduction

In current industrial society, humans suffer everyday exposure to chemical substances that may contain toxic elements through breathing and feeding. In India, severe health diseases caused by abnormal high levels of environmental arsenic (As) have been registered [1] and symptoms of gastrointestinal, dermatologic, musculoskeletal, circulatory and neurologic diseases linked to As overexposure have been documented. Chronic As toxicity states are characterized by general weakness, prostration, muscular aches, intestinal disorders and peripheral neuropathies caused by the increased conduction velocity of the action potentials in certain nerves [2]. In Europe, As intake has been measured. Low dietary intakes of As and mercury (Hg) were found among children from a coastal area of Germany, being out of toxic concentrations [3].

Beryllium (Be) is a toxic mineral present in industry throughout the world, its organic overage by inhalation may provoke several lung diseases, including cancer. Be toxicity pathologies are, among others, cardiovascular damage (ventricular hypertrophy), cancer (granulomatous lesions, especially in the lungs), endocrine damage (testes and prostate), blood disorders (changes in red cell levels) and liver damage (possible carcinoma) [4]. Carcinogenic properties of Be have been documented [5].

Cadmium (Cd) is a widespread industrial toxic element [6].

---

*Abbreviations:* $VO_{2max}$, maximum oxygen uptake; SG, sportsmen group; AG, aerobic sportsmen group; ANG, anaerobic sportsmen group; MG, aerobic-anaerobic group; CG, control group

[☆] Name exercise p of the laboratory where the work was carried out: Laboratory of Exercise Physiology, School of Sport Sciences, University of Extremadura.

[*] Corresponding author.

*E-mail address:* mmaynarm@gmail.com (M. Maynar-Mariño).

http://dx.doi.org/10.1016/j.jtemb.2017.10.007
Received 9 June 2016; Received in revised form 12 June 2017; Accepted 17 October 2017

**Table 1**
Anthropometric and cardiorespiratory characteristics of control and sportsmen groups.

| | Control (n = 31) | Sportsmen (n = 80) | Aerobic (n = 28) | Anaerobic (n = 24) | Aerobic-Anaerobic (n = 28) |
|---|---|---|---|---|---|
| Height (m) | 1.768 ± 0.057 | 1.76 ± 0.07 | 1.77 ± 0.05 | 1.73 ± 0.07 | 1.80 ± 0.05 |
| Weight (kg) | 78.21 ± 12.19 | 65.31 ± 7.55$^{***}$ | 64.95 ± 7.10$^{***}$ | 64.91 ± 8.46$^{***}$ | 73.78 ± 6.12*$^{\#\#\#\dagger\dagger\dagger}$ |
| $\Sigma 4$ skinfolds (mm) | 52.02 ± 23.77 | 35.12 ± 9.29$^{***}$ | 32.56 ± 8.75$^{***}$ | 33.66 ± 9.87$^{***}$ | 38.25 ± 10.06$^{**\#}$ |
| $\Sigma 6$ skinfolds (mm) | 88.82 ± 34.5 | 45.85 ± 16.69$^{***}$ | 49.69 ± 14.84$^{***}$ | 56.32 ± 16.65$^{**\#\#}$ | 59.49 ± 17.10$^{**\#\#\#}$ |
| VO2Máx (mL/min/kg) | 41.89 ± 7.509 | 64.08 ± 5.27$^{***}$ | 66.17 ± 8.362$^{***}$ | 61.23 ± 3.004$^{***\#}$ | 59.85 ± 4.539$^{**\#\#\dagger\dagger\dagger}$ |
| Basal Hr (bt/min) | 71.58 ± 7.38 | 59.75 ± 9.66* | 54.90 ± 10.85$^{**}$ | 62.85 ± 7.57$^{*\#\#}$ | 57.21 ± 10.51$^{*\dagger\dagger\dagger}$ |

Student t Test: (*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$) differences among Control and Aerobic, Anaerobic and Aerobic-Anaerobic groups. (#$p < 0.05$; ##$p < 0.01$; ###$p < 0.001$) differences among Aerobic and Anaerobic and Aerobic-Anaerobic groups.(†$p < 0.05$; ††$p < 0.01$; †††$p < 0.001$) differences between Anaerobic and Aerobic-Anaerobic groups.

Exposure ways to Cd are pollution, environmental concentrations and intake, so the possibilities of body Cd toxicity are relatively frequent [7]. Furthermore, tobacco smoking dramatically increases human Cd exposure [8]. Exceeding organic Cd may induce kidney damage, delayed growth, reproductive disorders, hypertension, and even cancer [9,10].

Other important toxic element is Cesium (Cs). In Japan, recent surveys have reported an increased presence of radioactive Cs in the environment due to an accident in a nuclear power station. An increment in Cs exposure can be harmfully toxic and could cause gastrointestinal discomfort, hypotension, syncope and numbness or lips tingling [11].

Lead (Pb) is a multipurpose industrial element used as a cooking glass container and paint compound [12], so, human nearby environment is somehow contaminated by Pb. Nowadays, Pb additive is forbidden in gasoline in most countries in the world, however, old plumbing has been found as Pb exposure major source. The effects of Pb in cardiovascular, reproductive [13], renal [14], and immune systems [15] are well-known; moreover, bones and teeth can also be affected by Pb [16]. It has also been confirmed that an elevated Pb exposure throughout life is associated with an increased risk of Alzheimer's disease [17]. It has also been identified as a possible carcinogen [18].

Considering all the above-mentioned reports, it seems clear that numerous sources of contamination and toxicity for human body are widespread in our current environment, especially in high-industrialized areas, so, for human health, there is a need to find measures which can help to prevent harmful amounts of those elements in the human body as well as to avoid its derivative diseases. One of this preventive measures against toxic minerals can be exercise and physical training.

The effect of physical exercise on organic toxic minerals has been barely studied in international bibliography, and its result has been researched just in plasma and urine. In this sense, Rodríguez-Tuya, Pinilla, Maynar, García-Moncó and Sánchez [19] found in their study that high-level athletes had lower plasma concentrations of Cd and Pb than subjects with lower levels of physical activity. Llerena, Maynar, Barrientos, Palomo, Robles and Caballero [20] pointed out in their study that toxic metals concentrations in urine were higher in the well-trained athletes than in the non-sportsmen group. This leads us to hypothesize that regular physical activity can induce adaptative organic changes in order to avoid mineral toxicity from environmental overexposure.

The present study aims to evaluate the influence of physical exercise (aerobic, anaerobic and aerobic-anaerobic training) in seric toxic minerals concentrations.

## 2. Materials and methods

### 2.1. Participants

This research was carried out under the Helsinki Declaration ethic guidelines, actualized in the World Medical Assembly in Seoul 2008, for the human's investigation. All the participants were informed about the purpose of the study and gave their voluntary signed informed consent.

80 professional sportsmen and 31 sedentary males participated in the present survey. All of them were living in Cáceres (Spain). They all completed a nutritional questionnaire about their feeding habits to ensure they were not taking any vitamins, minerals or other supplementation and to guarantee they all had a similar diet. None of them smoked or consumed supplements of the metals studied. The athletes had been training regularly for the two previous years

The sportsmen were classified in four groups: Sportsmen group (SG; n = 80) of all the modalities (aerobic + anaerobic + aerobic-anaerobic) with and average age of 20 ± 3 years; aerobic sportsmen group (AG; long distance runners; n = 28) with an average age of 21 ± 4 years; anaerobic sportsmen group (ANG: judo and speed athletes; n = 24) with an average age of 17 ± 2 years; and aero-anaerobic sportsmen group (MG: professional football players; 28 individuals) with an average age of 22 ± 4 years. The control group (CG) was formed by 31 sedentary students, with an average age of 21 ± 3 years. Anthropometric and cardiorespiratory characteristics of all participants are showed in Table 1.

### 2.2. Anthropometric measurements

The participants' morphological characteristics were measured in the morning and always at the same time (09:00 A.M). Body height was measured to using a wallmounted stadiometer (Seca 220), and body weight was measured using calibrated electronic digital scales, (Seca 769) in barefoot conditions. Body mass index was calculated by dividing the weight (in kg) by the height (in $m^2$). Body fat content was estimated from the sum of 4 skinfolds (abdominal, suprailiac, tricipital and subescapularis) and from the sum of 6 skinfold ($\Sigma 4+$ thigh and calf skinfolds). The skinfolds thickness was measured with a Harpenden caliper. Measurements were made by the same operator, skilled in kinanthropometry techniques.

### 2.3. Exercise test

To measure the different fitness levels of sportsmen and control groups, a maximal progressive exercise test was made. The protocol of the test consisted of running on a treadmill (Powerjoc. Uk), until exhaustion at a starting speed of 10 km/h, which increased 1 km/h every 400 m, with a stable slope of 1% (Niemalä et al., 1980). To perform the test, a Polar pulsometer (Polar. Norway) and an ergospirometer system equipped with a gas analyzer (Metamax. Cortex Biophysik. Gmbh. Germany) were used.

All participants were tested at the same times, from 9:00 AM to 12:00 PM Sportsmen and Controls followed exactly the same protocol to determine their performance variables.

### 2.4. Blood samples collection

Blood sample collection conditions, blood treatments as well as collection devices were identical for sportsmen and controls; At nine o'clock in the morning 5 mL of antecubital venous blood of were drawn