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# Carbohydrate beverages attenuate bone resorption markers in elite runners☆,☆☆

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ABSTRACT

*Objective.* We evaluated the effects of carbohydrate (CHO) supplementation on markers of bone turnover in elite runners.

*Design.* Twenty-four male runners were randomly assigned to two groups – a CHO and a control (CON) group – using a double-blind design. The participants were submitted to an overload training program (days 1–8), followed by a high-intensity intermittent running protocol (10 × 800 m) on day 9. They received a maltodextrin solution (CHO group) or a placebo solution as the CON equivalent, before, during, and after these protocols.

*Results.* After 8 days of intensive training, baseline levels of osteocalcin (OC) decreased in both CHO and CON groups (before: 28.8 ± 3.6 and 26.6 ± 2.4 ng/ml, after: 24.8 ± 3.0 and 21.9 ± 1.6 ng/ml, respectively, $p < 0.01$). On day 9, at 80 min of the recovery period, carboxy-terminal of telopeptide type I collagen (CTX) serum concentration was suppressed in the CHO group (0.3 ± 0.1 ng/ml) vs. 0.6 ± 0.0 ng/ml for the CON group ($p < 0.01$). CHO supplementation was effective in decreasing CTX levels from baseline to recovery (0.5 ± 0.1 ng/mL to 0.3 ± 0.1 ng/mL, $p < 0.001$), while an increase from 0.4 ± 0.0 ng/mL to 0.6 ± 0.0 ng/mL ($p < 0.001$) was observed in the CON group.

*Conclusion.* CHO beverage ingestion attenuated the exercise-induced increase in CTX concentration, suggesting that CHO supplementation is a potential strategy to prevent bone damage in athletes.



## 1. Introduction

Athletes have higher bone turnover than sedentary individuals [1]. Intensive training combined with an inadequate diet can lead to overtraining syndrome, which may reduce athletic performance and play a role in muscle, joint, and bone stresses and injuries, besides several other physiological, biochemical, and psychological complications affecting athletes' professional career [2–4].

Bone mass can be viewed as the net product of two metabolic processes, bone formation and bone resorption, coupled in a basic multicellular unit [5]. During a training program, runners expose their lower extremity bones and joints to large repetitive axial loads [6,7]. Such extremes of

*Abbreviations:* CHO, carbohydrate; CON, control; OC, osteocalcin; CTX, carboxy-terminal of telopeptide type I collagen; P1NP, procollagen type 1N propeptide; ALP, bone alkaline phosphatase; PTH, parathyroid hormone; HPA, hypothalamic–pituitary–adrenal; DXA, dual energy X-ray absorptiometry.

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chronic loading influence the turnover rate of bone and cartilage; the changes in turnover rate are usually detectable through changes in bone turnover biomarkers [5].

Osteocalcin (OC) is a marker of bone formation that has an important association with energy metabolism and plays a role in fat and glucose metabolism, insulin secretion, and pancreatic β-cell proliferation [8]. Levels of carboxy-terminal of telopeptide type I collagen (CTX), a bone resorption marker, are altered with exercise intensity and may also influence glucose metabolism [9,10].

CTX levels have been reported to increase post-exercise [5,11], whereas no changes were observed in procollagen type 1N propeptide (P1NP) and bone alkaline phosphatase (ALP) serum concentrations, both related to bone formation. On the other hand, in the study by Herman [12], OC decreased with moderate exercise at 75% and increased with intense exercise at 95% in athletes, besides an increase in CTX levels.

These data suggest that strenuous exercise may induce osteoclastic activity that is not necessarily accompanied by a compensatory increase in osteoblastic activity.

In addition to mechanical loading, bone turnover is regulated by several hormones. It is known that parathyroid hormone (PTH) and cortisol inhibit osteoblastic activity [13,14], gonadal steroids and IGF-1 inhibit the osteoclasts, and GH increases the osteoblastic activity during energy deficit. Moreover, activation of the hypothalamic–pituitary–adrenal (HPA) axis and the resulting hypercortisolemia are some of the main factors suppressing the hypothalamic–pituitary–gonadal (HPG) axis during exercise stress and inducing bone fragility [15]. All these changes are observed in athletes, increasing the risk for developing osteoporosis and stress fractures, which are common disorders in this group [16].

Diet and nutritional status have traditionally been the most relevant factors in the management of skeletal health and have helped to mitigate some losses [6,17]. However, the importance of CHO supplementation in bone markers during intense exercise has not been investigated in athletes.

If CHO beverages attenuate post-exercise bone resorption, we suggest that this nutritional strategy is needed for athletes to prevent bone damage while engaged in intensive training. We hypothesized that athletes receiving CHO supplementation during a protocol consisting of 8-day intensive training followed by a session of intermittent high-intensity running have less bone stress afterwards.

This study aimed to investigate the impact of intensive training and CHO beverages on bone biochemical markers in elite runners.

## 2. Methods

### 2.1. Subjects, carbohydrate (CHO) supplementation, and diet

Twenty-four elite male endurance runners (28.0 ± 1.2 years) training for the last 8.6 ± 1.1 years participated in the study. The protocol was approved by the Local Committee on Ethics of Human Research, and written informed consent was obtained from all subjects. These runners were randomly assigned to the CHO group or control (CON) group using a double-blind design. The two groups were matched for maximal oxygen consumption ($VO_2$max), body weight, and age. Both groups received isocaloric diet, with greater intake of CHO in the CHO group versus the CON group. The CHO group consumed 1 g maltodextrin/kg body weight per hour of running as a supplement during 8 days of training in the morning, corresponding to a daily dietary CHO of 61%, whereas the CON group was given a placebo solution. The diet consumed by the CON group provided a daily CHO of 54%. Data regarding the physical profiles of the athletes are shown in Table 1. The CHO and CON groups consisted of 12 subjects each, presenting the following mean physical profile, respectively: $VO_2$max: 69.8 ± 2.2 and 68.5 ± 1.9 mL · kg$^{-1}$ · min$^{-1}$; body weight: 60.2 ± 1.4 and 62.3 ± 1.6 kg; and height: 169.5 ± 2.0 and 170.2 ± 2.5 cm (Table 1). There were no differences in these parameters between the two groups.

### 2.2. Overload training program and intermittent running protocol

After determination of the physical profile, the participants underwent 13 training sessions over a period of 8 days. Eight sessions were held in the morning (days 1–8) and five in the afternoon (days 1–5). The training protocol has been described previously [2]. After the overload training program (days 1–8), the athletes arrived at the running track on day 9 after a 12-h fast and blood samples were collected. Next, the athletes ingested a standard breakfast 140 min before the beginning of the intermittent running protocol. The protocol was performed in the morning on a synthetic surface running track. The running session consisted of 10 series of 800 m (10 × 800 m) performed at a speed corresponding to the 3-km time trial (Vm3km) performed previously, with resting intervals of 1 min and 30 s, and two maximum performance tests of 1000 m. The first maximum performance test (1st 1000 m) was performed 20 min before the beginning of the intermittent exercise session and the second test (2nd 1000 m) was performed 20 min after the end of the intermittent exercise session. The CHO group received a 7% maltodextrin solution and the CON group received water artificially sweetened with aspartame before (−30 min), during (after the 1st 1000 m, after every 2 series of 10 × 800 m), and immediately after the intermittent running

**Table 1 – Mean (±SEM) biometric and physical profile of the participants ($n$ = 24).**

| | Carbohydrate | Control | P value (CHO *vs.* Control) |
|---|---|---|---|
| Age (years) | 29.1 ± 1.6 | 26.9 ± 1.9 | 0.40 |
| Height (cm) | 169.5 ± 2.0 | 170.2 ± 2.5 | 0.84 |
| Weight (kg) | 60.2 ± 1.4 | 62.3 ± 1.6 | 0.34 |
| Percent body fat [a] | 8.3 ± 0.3 | 9.9 ± 0.5 | 0.0043 |
| HRmax (bpm) | 175.9 ± 1.4 | 177.5 ± 2.4 | 0.60 |
| $VO_2$ max (ml/kg/min) | 69.8 ± 2.2 | 68.5 ± 1.9 | 0.67 |
| Duration of training (years) | 9.5 ± 1.6 | 7.4 ± 1.2 | 0.35 |

[a] Evaluated by bone densitometry (DXA; Hologic QDR, 2000 W).