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Zinc status at baseline is not related to acute changes in serum zinc concentration following bouts of running or cycling

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ABSTRACT

Zinc status is implicated in physiological functions related to exercise performance and physical activity. We have previously demonstrated significant changes in serum zinc concentrations following a bout of aerobic exercise, suggestive of a relationship between zinc metabolism and exercise-related functions. In the present study, we aim to determine the association between pre-exercise serum zinc concentration and immediate changes in serum zinc concentration following an aerobic exercise bout.

We have previously conducted a systematic literature search of PubMed, Web of Science, Scopus and SPORTDiscus, for studies that investigated the acute effects of aerobic exercise on zinc biomarkers. In the current study, we undertook a secondary analysis using mixed effects meta-regression modelling to determine the relationship between baseline serum zinc concentration and the change in serum zinc concentration immediately after exercise.

Meta-regression models revealed no significant relationship between baseline serum zinc concentration and the change in serum zinc concentration following a bout of exercise when all comparisons were included (slope –0.11 ± 0.07 [standard error]; $P > 0.05$). When comparisons were stratified by exercise modality, no significant relationships were observed for exercise bouts involving cycling or running. The current analyses were limited by the available literature and low statistical power of the meta-regression models.

Based on the current available data, the present analysis revealed limited evidence for a relationship between pre-exercise serum zinc concentration and immediate changes in serum zinc levels following a bout of aerobic exercise. Subgroup meta-regression analyses stratified by the mode of exercise bouts did not differ from the overall results. This suggests that zinc status at baseline is not related to acute changes in serum zinc concentration following bouts of aerobic exercise.

1. Introduction

Zinc is an essential mineral that plays a role in multiple functions, in particular, zinc status has been implicated in physiological functions related to exercise performance and physical activity [1,2]. Reduction in cardiovascular capacity and muscle endurance during exercise can be induced under zinc-depleted conditions [3], potentially mediated through the role of zinc in activities of enzymes, such as lactate dehydrogenase, superoxide dismutase and carbonic anhydrase. Further, cellular studies of skeletal muscles have indicated that zinc serves important roles in energy metabolism [4], and the activation and proliferation of satellite cells in muscle regeneration and growth [5]. The effects of inadequate zinc status on functional outcomes pertinent to exercise performance [1,2] suggest that baseline zinc status may be related to homeostatic controls involved in exercise and recovery.

Zinc is widely distributed in all body organs and tissues, with the liver playing a central role in systemic zinc metabolism by regulating a pool of zinc that is rapidly exchangeable with plasma and other tissues [6,7]. The tissue uptake of zinc is co-ordinately regulated by multiple cellular zinc transporters [8], classified into two groups according to their function [9]: zinc transporters (ZnT) and zir-, irt-like proteins (ZIP). A number of genetic polymorphisms in multiple zinc transporters has been associated with adverse phenotypic traits [10,11], for instance ZnT8 and diabetes risk [12], and ZIP8 and cardiovascular diseases risks [13]. Our data suggest that the gene expression of ZIP7 is positively correlated with physical activity levels in healthy adults [14], indicating that the relationship between exercise and zinc metabolism is regulated by cellular and systemic mechanisms.

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We have previously demonstrated significant changes in serum zinc concentrations following a bout of aerobic exercise [15,16]. Specifically, a significant increase in serum zinc concentration was found immediately following exercise [15] and a greater reduction of serum zinc concentration, to below the baseline levels, up to four hours upon exercise cessation [16]. Further, in a zinc depletion/repletion study, Lukaski et al. suggested that baseline zinc status was an important factor in determining the change in serum zinc concentration following exercise [17]. The relationship between baseline zinc status and change in serum zinc concentration immediately following exercise has not been examined with the incorporation of data from multiple studies, *e.g.* by meta-regression.

In the present study, we aim to determine the association between pre-exercise serum zinc concentration and immediate changes in serum zinc concentration following an aerobic exercise bout.

2. Methods

The methodology of the systematic review and meta-analysis, characteristics of included studies were summarised previously in papers exploring the effects of aerobic exercise bouts on zinc biomarkers [15,16]. Details on the search strategy, study eligibility criteria, data extraction and quality assessment of selected studies were described previously [15,16]. Briefly, we conducted a systematic literature search of electronic databases for studies that investigated the acute effects of aerobic exercise on zinc biomarkers. Meta-analyses of change in serum zinc concentration were carried out by mean difference of serum zinc levels from baseline (pre-exercise) and immediately after exercise values, in random-effects models. In the current set of publications, we combined plasma and serum zinc concentrations to represent zinc concentration in the systemic circulation. While there are methodological differences in the processing of blood specimens, no substantial differences were found in zinc concentrations between plasma or serum [18].

In the present study, we undertook a secondary analysis to determine the effect of baseline zinc status on immediate changes in serum zinc concentration following an aerobic exercise bout. Mean differences of serum zinc concentration in each comparison were calculated from values at baseline (pre-exercise) and immediately after exercise. One study [19] did not provide data of baseline plasma zinc concentration and therefore was excluded from the current analysis. The PRISMA flowchart depicting study inclusion in the current secondary analysis is shown in Fig. 1. Mixed effects meta-regression modelling using method of moments was performed to determine the relationship between baseline serum zinc concentration and the change in serum zinc concentration immediately after exercise. The comparisons were further categorised into the mode of exercise bouts (running or cycling), to examine potential differences as a result of exercise modes. Sensitivity analyses were conducted to identify any impact of individual or groups of comparisons on the meta-regression models.

3. Results

The study characteristics of the systematic literature review with primary meta-analyses of the effects of aerobic exercise on serum zinc concentrations were reported previously [15,16]. Briefly, data from 46 comparisons of different populations groups (provided by 34 included studies) showed significant increase of serum zinc concentration immediately after exercise [15]. Majority of the included studies failed to report dietary zinc intake, as well as supplemental zinc use. In studies where the intervention was a nutrient supplementation, the baseline results of the exercise test were taken. Exercise bouts involving running (provided by 16 studies) elicited the greatest change in serum zinc concentration (+0.71 ± 0.26 μmol/L; Fig. 2), whereas cycling (data from 20 studies) produced a smaller change in serum zinc levels (+0.43 ± 0.22 μmol/L; Fig. 2).

3.1. Baseline serum zinc concentrations and exercise-induced changes in serum zinc concentration

The mean serum zinc concentration at baseline ranged from 8.23 to 21.89 μmol/L (Table 1). Using the serum zinc concentration cutoff for increased risk of zinc deficiency [18], the baseline zinc concentrations for three studies were ≤ 10.7 μmol/L. Three studies reported mean zinc concentration > 18 μmol/L, the typical upper end of the reference range [20,18].

The calculated mean change of serum zinc concentration immediately after exercise for individual comparisons ranged from -3.0 to +11.93 μmol/L. Two comparisons were identified as outliers in the change of serum zinc concentration following exercise as they were significantly different from other comparisons [15].

3.2. Relationship between exercise-induced changes and baseline serum zinc concentrations

Meta-regression models revealed no significant relationship between baseline serum zinc concentration and the change in serum zinc concentration following a bout of exercise when all comparisons were included (slope –0.11 ± 0.07 [standard error]; $P > 0.05$; Fig. 3). When comparisons were stratified by exercise modality, no significant relationships were observed for exercise bouts involving cycling (slope –0.001 ± 0.08; $P > 0.05$; Fig. 4) or running (slope –0.31 ± 0.27; $P > 0.05$; Fig. 5). When the outlying comparisons were omitted from the meta-regression models, no substantial changes were noted to the overall results when all comparisons were included (slope –0.10 ± 0.06; $P > 0.05$) or with running exercise bouts only (slope –0.11 ± 0.23; $P > 0.05$).

4. Discussion

Based on the current analysis, no relationship was observed between pre-exercise serum zinc concentration and immediate changes in serum zinc levels following a bout of aerobic exercise. Subgroup meta-regression analyses stratified by the mode of exercise bouts did not differ from the overall results. The majority of the available comparisons included participants with baseline serum zinc concentration within the reference range. The current evidence suggests that zinc status at baseline is not related to acute changes in serum zinc concentration following bouts of aerobic exercise.

The current findings are in contrast to the initial investigation on the relationship between zinc status and exercise-induced changes in serum zinc concentration. The first study aimed at exploring the potential of using post-exercise changes of serum zinc as a functional test of zinc status by Lukaski and colleagues [17], under metabolic-ward conditions. In the zinc depletion-repletion study, exercise induced higher levels of plasma zinc efflux when dietary zinc intake was low, compared to adequate zinc intake, suggestive of a relative reduction in circulating exchangeable zinc during zinc depletion. Fluctuations of serum zinc concentrations appear to be dependent on the mode of exercise possibly due to the activation of different groups of skeletal muscle and hence generating varied levels of metabolic responses [15,21]. In the present analysis, the observed heterogeneity in the responses of serum zinc concentrations following exercise may be explained by the range of exercise modes and intensities.

We proposed that baseline and exercise-induced changes in serum zinc concentrations may be modulated by inflammatory and/or haemodynamic changes induced by exercise [15], however the available data does not allow for this investigation to be carried out in a comprehensive manner. In the only study of zinc kinetics following exercise, Volpe et al. reported a significant reduction in plasma zinc concentration during the recovery phase from an exhaustive cycling exercise bout [22]. The two-pool kinetic model that was applied to the data suggested that while plasma zinc levels decreased following exercise,