Low testosterone in male endurance-trained distance runners: impact of years in training

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Dear Sir:

Over the last several decades, many research groups have sought to understand how exercise affects and disrupts the function of the hypothalamic-pituitary-gonadal (HPG) axis in men and, in particular, its effect on resting testosterone levels. Researchers have principally focused on endurance-based exercise activities as these are clearly more closely associated with the development of low resting testosterone and the “exercise-hypogonadal male condition” (EHMC). In 2005, our research group coined the term EHMC and developed criteria for the symptomology associated with it in male athletes (Table 1) [1]. The reproductive changes associated with EHMC development have potentially serious health implications relative to fertility, bone health, and metabolic function in men (see reference [2] for an overview).

For the above reasons, there has recently been renewed interest in the effect of exercise on the reproductive system of men. Meanwhile, the IOC Medical Committee has released a report proposing an overarching terminology for sportsmen and women having reproductive-endocrine disruptions and alterations, namely “Relative Energy Deficiency in Sports” (RED-S) [3]. One of the central tenets of this report suggests that the reproductive changes seen in men, as well as in women, who do athletics are related to the development of low energy availability (LEA) [4]. In women, this relationship is strongly supported by research findings; however, in men, the assumption has yet to be fully substantiated [5]. More research is therefore necessary before determination of whether LEA is

universal and similar in its effect on men and women and on their reproductive function.

One of the common practical questions concerning men engaged in endurance training and at risk for EHMC is as follows: *To what degree of magnitude are their testosterone levels lowered?* Typically, research reports demonstrate that testosterone is statistically significantly less than a given reference value. However, how much of a reduction from expected hormonal reference values or as compared to individuals who are healthy but are non-exercisers is not clearly addressed in the literature. Thus, we chose to examine and review archived data from studies within our research group which looked at men engaged in endurance exercise training in order to assess the magnitude of change in resting testosterone levels. In particular, anecdotal observations suggested that years of training was a critical factor in influencing testosterone levels of endurance-trained men; hence, we stratified by this factor.

Examination of data on endurance athletes

The data review involved examining a number of our group’s data sets from which a total of 196 male endurance-trained distance runners and their corresponding, respective matched controls were identified. We delimited ourselves to examining distance runners (≥ 10 km competitive events or greater) who trained a minimum of 7 h a week (or more) and who had been running for at least 1 year or more. The design approach in these studies was observational cross-sectional (case-control) as each endurance runner was matched with a healthy, non-exercising control subject. Matching factors were as follows: age (± 1 year), BMI (± 1 kg/m²), and ethnicity. All subjects were required to have a stable body weight (no weight changes $> 3\%$ during the last 4 months) and were medically screened to determine state of health; all distance runners were asked to pursue a period of normal,

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Table 1 The common characteristics and traits of men displaying the “exercise-hypogonadal male condition” [1]

- (i) Low resting basal testosterone levels, typically only 50–75% that of normal, healthy, age-matched sedentary men.
- (ii) Low testosterone levels do not appear to be a transient phenomenon related to the acute stress of exercise.
- (iii) In many cases, it appears that an adjustment in the regulatory axis has occurred (to allow a new, lower set-point for circulating testosterone).
- (iv) A history of early involvement in organized sport and exercise training. This has resulted in these men having many years of almost daily exposure to high levels of physical activity.
- (v) The type of exercise training most frequently seen in these men is prolonged endurance-based activities such as distance running, cycling, race walking, and triathlon training.

steady-state training (no ramping-up to increase training load and/or tapering to reduce training loads) during the last 6 weeks and no major injury which curtailed training during the last 12 months. All subjects provided a morning (0700 to 0900 h) resting blood sample after a minimum of 8 h fasting and having no sexual activity (> 24 h before) and, for the runners, a minimum of 18 h discontinuation of any form of exercise training. Additionally, exercise training history, fatigue state, and running competitive performances were obtained through questionnaires. Blood samples were analyzed for total testosterone using standard clinical bioanalytical techniques (radioimmunoassay or enzyme-linked immunoassays) with appropriate quality control procedures for the relative time period of the study. Hormonal assays were batched and conducted so that the same analytical procedures were used for athletes and their matched controls.

Fig. 1 Testosterone levels of endurance-trained runners (age = 18–57 years) expressed as a percentage decrease of the non-exercising matched control subjects. For years training: 1 year, $n = 49$; 2 years, $n = 28$; 5 years, $n = 52$; 10 years, $n = 40$; 15+ years, $n = 27$

An individual runner’s testosterone values were expressed as a representation of their respective matched control subject. From this latter comparison, the runner’s testosterone levels are reported as a percent change (being greater than or less than that of their control reference subject). Hormonal responses for athletes were stratified and categorized by years of training: 1 year, $2 (\pm 1)$ years, $5 (\pm 2)$ years, $10 (\pm 2)$ years, and $> 15 (\pm 2)$ years. Responses for each of these year categories were statistically analyzed via an ANOVA and the Fisher *LSD* post hoc procedures.

Figure 1 illustrates that the longer an endurance runner is engaged in consistent and chronic endurance training, the lower their resting testosterone becomes ($p < 0.01$). The results suggest that the level of reductions observed plateaus at approximately -30% (after 5 years training), which was significantly lower than the reductions observed for individuals training < 5 years ($p < 0.001$), while no differences existed between 5, 10, and 15 years ($p > 0.05$).

Implications of data review

To our knowledge, these findings represent the largest published sample on the influence of chronic endurance training and the resulting effects on resting testosterone in men. The finding of lower testosterone in such men is not novel, but the training “dosage by years” impact is unique [5, 6].

Our intent was not to assess why the occurrence of low testosterone exists in these men; hence, we will not speculate

on this issue. However, in the case of EHMC, it is reported that endurance exercise training may result in an adaptive response in men such that their HPG axis regulation is re-set to facilitate lower overall testosterone production [6]. This latter issue is an area in which more research is needed.

The current findings point to the necessity for both clinicians and researchers to be mindful of the fact that male patients and research subjects who have extensive endurance exercise training backgrounds will show potential alterations in their resting testosterone levels. Thus, standard clinical reference norms and/or expected ranges of hormonal assessment may be inappropriate for these individuals. Future research is required in this area of reproductive endocrinology as low testosterone has critical implications for infertility, bone health, and energy metabolism in men [5, 7].

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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