



## Yes: Relative Energy Deficiency in Sport (REDs) Does Exist!

Margo L. Mountjoy<sup>1</sup> · Kathryn E. Ackerman<sup>2</sup> · David M. Bailey<sup>3</sup> · Louise M. Burke<sup>4</sup> · Naama Constantini<sup>5</sup> · Anthony C. Hackney<sup>6</sup> · Ida A. Heikura<sup>7,8</sup> · Anna K. Melin<sup>9</sup> · Anne Marte Pensgaard<sup>10</sup> · Trent Stellingwerff<sup>7,8</sup> · Jorunn Sundgot-Borgen<sup>11</sup> · Monica K. Torstveit<sup>12</sup> · Astrid Uhrenholdt-Jacobsen<sup>13</sup> · Evert Verhagen<sup>14</sup> · Richard Budgett<sup>15</sup> · Lars Engbretsen<sup>15</sup> · Uğur Erdener<sup>15,16,17</sup>

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“Questions open the door to dialogue and discovery. They are an invitation to creativity and breakthrough thinking. Questions can lead to movement and action on key issues; by generating creative insights, they can ignite change.” [1] Eric Voigt, Juanita Brown, David Isaacs (2003).

In keeping with this sentiment, the authors of the 2023 International Olympic Committee (IOC) REDs consensus statement acknowledge the scientific discourse generated in the recent publication “Does Relative Energy Deficiency in Sport (REDs) Syndrome Exist?” [2]. Curiosity and inquiry progress the scientific field by stimulating academic debate

and challenging assumptions through the varied lenses of interdisciplinary perspectives. We welcome this type of collaborative, critical debate.

Because we identified and embedded the scientific gaps in our knowledge of REDs within the IOC REDs consensus statement [3] and the accompanying supportive publications in the September 2023 *BJSM* REDs dedicated edition [4–10], there is much in the Jeukendrup et al. paper with which we agree. For example, we raised the same challenges and inaccuracies in measuring energy availability. In addition, we concur that the REDs Conceptual models, designed to facilitate athlete, coach, and parent comprehension of the potential risks associated with problematic low energy availability (LEA) (Fig. 1), are limited by the same thing that promotes their value and function: their simplicity. Hence, the REDs Physiological model [5] was developed to better address the complexity of physiological phenomena

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✉ Margo L. Mountjoy  
mmsportdoc@mcmaster.ca

<sup>1</sup> Department of Family Medicine, Michael G. DeGroot School of Medicine, McMaster University, Waterloo Regional Campus, 10B Victoria Street S, Waterloo, ON N2G 1C5, Canada

<sup>2</sup> Wu Tsai Female Athlete Program, Boston Children’s Hospital, Harvard Medical School, Boston, MA, USA

<sup>3</sup> Israel Cycling Academy, Tel Aviv, Israel

<sup>4</sup> Mary MacKillop Institute for Health Research, Australian Catholic University, Melbourne, Australia

<sup>5</sup> Shaare Zedek Medical Center, The Hebrew University, Jerusalem, Israel

<sup>6</sup> University of North Carolina, Chapel Hill, NC, USA

<sup>7</sup> Canadian Sport Institute Pacific, Victoria, Canada

<sup>8</sup> Exercise Science, Physical and Health Education, University of Victoria, Victoria, Canada

<sup>9</sup> Department of Sport Science, Linnaeus University, Kalmar/Växjö, Sweden

<sup>10</sup> Department of Sport and Social Sciences, Norwegian School of Sport Sciences, Oslo, Norway

<sup>11</sup> Department of Sports Medicine, The Norwegian School of Sport Sciences, Oslo, Norway

<sup>12</sup> Department of Sport Science and Physical Education, University of Agder, Kristiansand, Norway

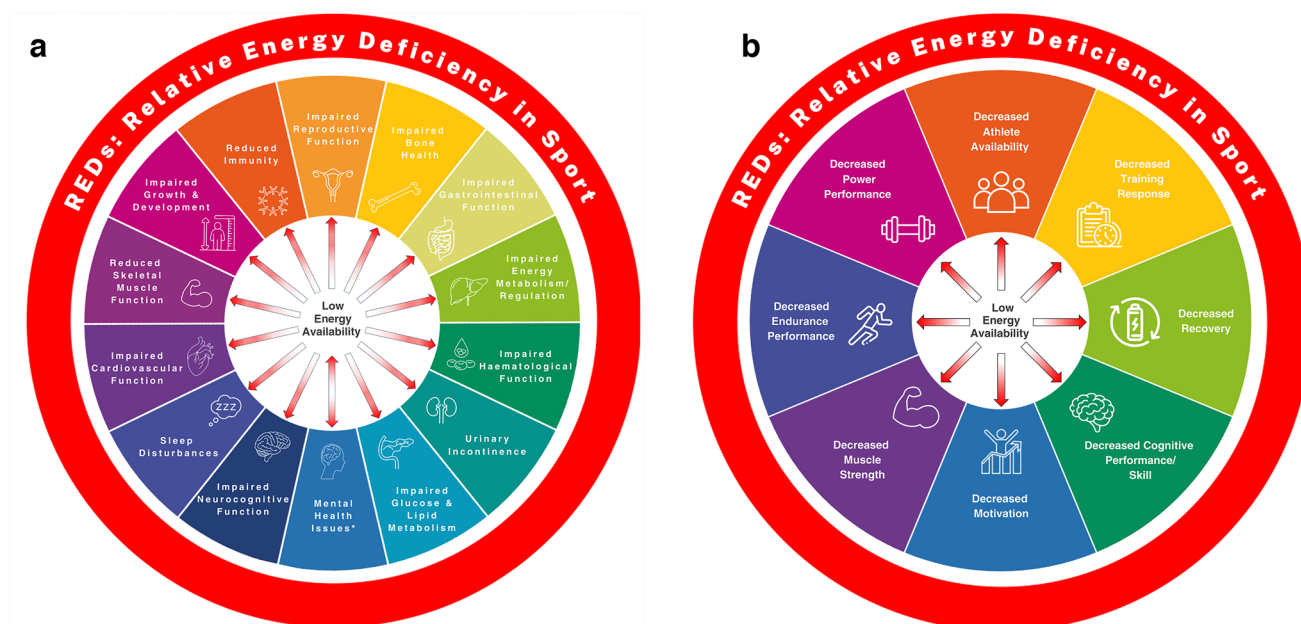
<sup>13</sup> International Olympic Committee Athlete’s Committee, Lausanne, Switzerland

<sup>14</sup> Amsterdam Collaboration on Health and Safety in Sports, Department of Public and Occupational Health, Amsterdam Movement Science, Amsterdam UMC, Amsterdam, The Netherlands

<sup>15</sup> International Olympic Committee, Lausanne, Switzerland

<sup>16</sup> Department of Ophthalmology, Hacettepe University, Ankara, Turkey

<sup>17</sup> World Archery, Lausanne, Switzerland



**Fig. 1** **a, b** REDs health and sports performance conceptual models: REDs conceptual models. The effects of LEA exist on a continuum. While some exposure to LEA is mild and transient, termed adaptable LEA (arrow depicted in white), problematic LEA is associated with various adverse REDs outcomes (arrow depicted in red). Panel

**a** depicts the health outcomes of REDs (\*Psychological consequences can either precede REDs or be the result of REDs.), and **b** depicts sports performance outcomes of REDs. Reproduced from Ref. [3] with permission from BMJ Publishing Group Ltd. LEA, low energy availability; REDs, Relative Energy Deficiency in Sport

and answer the questions identified by both author groups (Fig. 2). As stated by Burke et al. [5] in the REDs Physiological model manuscript:

“We encourage a sequence of activities to develop individual maps for each body system, which could then be integrated to acknowledge interrelationships and cross-talk among organs/systems... We hope that the development and continued evolution of these individual body system, physiologically-based models will enhance the understanding and exploration of the complex science underpinning REDs; that they assist clinicians in providing better education, prevention and treatment programmes for REDs” [5].

Burke et al. [5] posed the challenge of further developing the underpinning physiological pathways of REDs. This can be realised by applying the Olympic motto through collaborative efforts: “Faster, Higher, Stronger—Together!”.

## 1 Causation

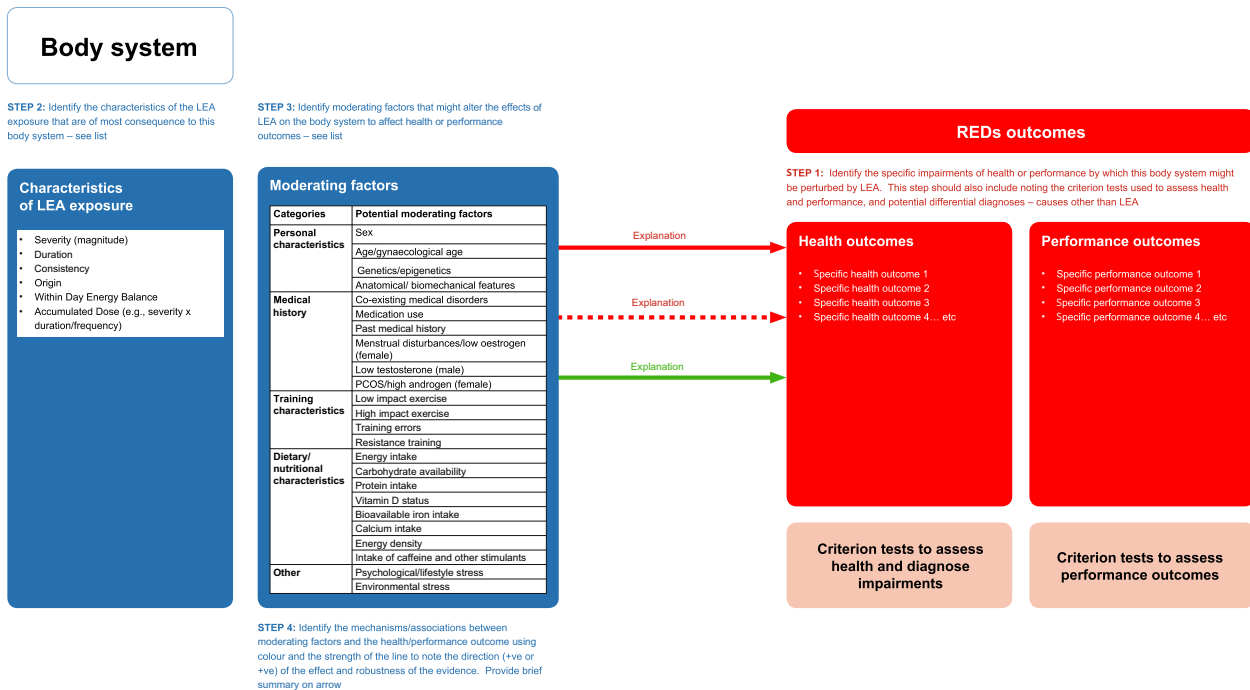
Let’s address the causation issue, as Jeukendrup and colleagues raised: “Very few studies can demonstrate causality between LEA and symptoms” [2]. In 1957, Ronald Fisher, a renowned statistician, penned a letter

in the *British Medical Journal* refuting an article that identified smoking as a cause of lung cancer. Fisher postulated that the article was.

“Nothing short of statistically illiterate fear-mongering. Surely the danger posed to the smoking masses was ‘not the mild and soothing weed’, but the organised creation of states of frantic alarm [11].”

Of course, we now know that smoking does cause lung cancer—although almost all supportive data are cross-sectional and correlational. Fisher, however, needed to be more convinced, as the statistical evidence at the time was correlational and lacked the control of confounding factors essential in randomised controlled trials (RCTs). Ethical research principles do not permit ‘gold-standard’ intervention RCTs (typically used to prove causation) in disease research. While correlations do not equal causation in single studies, a large totality of cross-sectional data can eventually be shown to be causative. We draw the reader’s attention to the words of Professor Emeritus Austin Bradford Hill in a lecture at the Royal Society of Medicine (1965):

“‘Hard-and-fast’ statistical rules do not clear away all uncertainty. They just help informed, well-intentioned people make the best decisions that they can. All scientific work is incomplete....and liable to be upset or modified by advancing knowledge. That does not confer upon us a



**Fig. 2** REDs Physiological Model. Template for developing the REDs Physiological Model for each body system identified in the REDs Health Conceptual Model. Each model will show how problematic LEA exposure, with various associated moderating factors, can lead to various REDs ‘outcomes’, represented by body system/health dysfunction(s) and potential performance impairment(s). This

template outlines four ‘actions’ (steps) to adapt and update the model as the future science of LEA/REDs evolves. Reproduced from Ref. [3] with permission from BMJ Publishing Group Ltd. LEA, low energy availability; PCOS, polycystic ovary syndrome; REDs, relative energy deficiency in sport

freedom to ignore the knowledge we already have, or to postpone the action that it appears to demand at a given time”. [12].

In this speech, Bradford Hill also presented nine criteria for determining causation from non-interventional data, which have helped define causation in syndromes and diseases where controlled studies are unethical to perform (e.g. that smoking causes lung cancer [13] and that repetitive head impacts cause chronic traumatic encephalopathy) [14].

Thus, we do not support the thesis of Jeukendrup et al., which states that long-term studies (months to years) of energy availability manipulation in controlled studies are required to determine the causation of REDs. This is both unethical and unfeasible. Indeed, this is also why the current 2023 IOC consensus authors still conservatively reference REDs as a ‘syndrome’—defined as a “*recognisable complex of symptoms and physical findings that indicate a specific condition for which a direct cause is not necessarily understood*”—versus a ‘disease’, in which “*causal mechanisms are identified*” [15]. As the totality of data is further developed, we recommend the application of the Bradford Hill criteria to assess the relationship between exposure to problematic LEA and the development of REDs. As emphasised in the 2023 IOC REDs consensus

statement, and again now, may this Letter to the Editor serve as a ‘call to action’ for sports scientists to work together to further the REDs scientific base as we believe that, one day, there will be enough evidence of a causal relationship to call REDs a disease.

## 2 Applying Science to the Art of Medicine

Despite our agreement with Jeukendrup and colleagues outlined above, we were perplexed by their discussion on the clinical approach to REDs. This may be due to their predominantly non-clinical authorship, which contrasts with our diverse authorship group of active clinicians and scientists (representing sports medicine, endocrinology, sports dietetics, sports psychology, sports science, sports physiology, coaching and athletes) with a vast cumulative clinical and lived experience of REDs in sports contexts. We do not see that Jeukendrup and colleagues addressed the question posed in the title: ‘Does REDs exist?’. To ascertain whether someone has REDs, one needs to implement the diagnostic criteria provided in the IOC REDs Clinical Assessment Tool-Version 2 (IOC REDs CAT2). Unfortunately, this tool is mentioned only once in the Jeukendrup article. It is misrepresented as a ‘questionnaire-based’ tool, despite most of the IOC REDs CAT2 criteria not being questionnaire-based



**Fig. 3** The IOC REDs CAT2 three-step protocol including step (1) screening, step (2) severity and risk assessment and stratification and step (3) clinical diagnosis and treatment. Reproduced from Ref. [3] with permission from BMJ Publishing Group Ltd

(Fig. 3). Furthermore, the authors focus on the challenges of measuring and interpreting resting metabolic rate, immune function and bone biomarkers, none of which are diagnostic indicators in the IOC REDs CAT2.

We agree that diagnosing REDs by symptom presentation alone is insufficient. To improve diagnostic accuracy, the IOC REDs CAT2 includes eight female- and eight male-specific indicators, representing *both* clinical signs and symptoms [16]. These indicators are weighted according to the strength of their scientific evidence. They also underwent a rigorous consensus process following the RAND-UCLA Appropriateness Method (RAM) [17] via expert voting statements requiring 80% agreement. In addition, using validity and usability assessments, the IOC REDs CAT2 was tested against the medical opinions of an external cohort of sports physicians ( $n = 40$  assessments), demonstrating a positive correlation ( $r = 0.885$ ) between the IOC REDs CAT2 and the physicians' diagnoses and management [9]. A recent study implemented the IOC REDs CAT2 in over 200 ( $F = 143$ ,  $M = 70$ ) elite athletes across 13 sports. This study showed statistically significant differences in nearly all diagnostic clinical indicators across each traffic-light outcome, representing the varying severity and risk of REDs, indicating the validity of the tool and the existence of REDs in both male and female athletes [18].

“The CAT2 has high validity in demonstrating current severity of REDs, with increased future risk of self-reported bone stress injury in athletes with a more severe REDs traffic light category.” [18].

REDs is a ‘diagnosis of exclusion’ (this concept is mentioned numerous times in the REDs publications [3, 9]), which is similar to other medical diagnoses (e.g. irritable bowel syndrome, Bell’s palsy, panic attack). Physicians are clinically trained to assess for other causes, or ‘differential diagnoses’, of concurrent signs and symptoms in patients [19]. Jeukendrup et al. propose an “Athlete Health and Readiness Checklist” (AHaRC) decision tree to “maintain athletes’ health and

performance”. We welcome tools to improve clinical accuracy and efficiency. However, internal and external validation in clinical settings is necessary to ensure efficacy and accuracy, and we encourage this important exercise for the AHaRC. Adding the AHaRC to the literature without such rigour seems premature and risks confounding clinical practitioners.

### 3 Conclusion

As sports medicine physicians, psychologists, physiologists, scientists, dietitians, coaches and athletes, we—the IOC consensus co-authors—know that REDs exist. We see and treat it in our athletes daily. To benefit athletes worldwide, let us work together to avoid confusing the sports community and instead answer the existing scientific gaps through curiosity, inquiry, and collaborative, athlete-centred, interdisciplinary research. In doing so, we will evolve the field to develop evidence-informed, best-practice REDs prevention strategies, diagnostic criteria and treatment regimens.

“The important thing is not to stop questioning.”  
 Albert Einstein (LIFE magazine, 2 May 1955).

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### Declarations

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**Conflict of Interest** Margo Mountjoy is a Deputy Editor of the *BJSM* and a member of the *BJSM* IPHP Editorial Board. Kathryn Ackerman is a Deputy Editor of the *BJSM* and an Associate Editor of the *BJSM* IPHP. Louise Burke is a Special Projects Editor for the *International Journal of*

*Sport Nutrition and Exercise Metabolism*. Naama Constantini is an Editorial Board Member for *Medicine and Science in Sport & Exercise*, *Clinical Journal of Medicine*, and *Translation Sport Medicine*. Anthony Hackney is an Associate Editor for *Frontiers in Physiology*. Evert Verhagen is an Associate Editor of the *BJSM*, an Associate Editor of the *BJSM IPHP*, and Editor in Chief of *BMJ Open Sports and Exercise Medicine*. Richard Budgett is a former IOC Medical and Scientific Director. Lars Engebretsen is a former IOC Head of Science Activities, and an Editor of *BJSM IPHP*. Uğur Erdener is an IOC member and the former Chair of the IOC Medical and Scientific Commission. The remaining authors have no competing interests to declare.

**Ethics Approval, Consent, Data, Material, and Code Availability** Not applicable.

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