



QUALITY IN SPORT

eISSN 2450-3118 · Open Access · Peer-reviewed

apcz.umk.pl/QS Nicolaus Copernicus University in Toruń



Syguda A, Tarnawska K, Strózik A, Szcześniak A, Matyja W. Beyond BMI: Body Composition Misclassification and Relative Energy Deficiency in Sport as Overlooked Threats to Athletic Performance – A Narrative Review. *Quality in Sport*. 2026;67:74351. <https://doi.org/10.12775/QS.2026.67.74351>

ARTICLE TIMELINE

Received: 15.07.2026. Revised: 02.08.2026. Accepted: 02.08.2026. Published: 10.08.2026.

The journal has been awarded 20 points in the parametric evaluation by the Polish Ministry of Higher Education and Science (Annex to the announcement of 05.01.2024, No. 32553). Unique Journal Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).

Punkty Ministerialne z 2019 – aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych). © The Authors 2026.

OPEN ACCESS · CC BY-NC-SA 4.0 This article is published with open access under the License Open Journal Systems of Nicolaus Copernicus University in Toruń, Poland, and is distributed under the terms of the Creative Commons Attribution Non-commercial Share Alike License (<http://creativecommons.org/licenses/by-nc-sa/4.0/>), which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the work is properly cited. The authors declare no conflict of interest regarding the publication of this paper.

Beyond BMI: Body Composition Misclassification and Relative Energy Deficiency in Sport as Overlooked Threats to Athletic Performance – A Narrative Review

Aleksandra Syguda [AS]

ORCID: 0009-0008-1314-7120

E-mail: aleksandra.syguda28@gmail.com

Medical University of Silesia, Poniatowskiego 15, 40-055 Katowice, Poland

Kamila Tarnawska [KT]

ORCID: 0009-0003-1146-7212

E-Mail: kamilatarnawska79@gmail.com

Medical University of Silesia, Poniatowskiego 15, 40-055 Katowice, Poland

Anna Strózik [AST]

ORCID: 0009-0009-3813-8770

E-Mail: a.strozik01@gmail.com

Medical University of Silesia, Poniatowskiego 15, 40-055 Katowice, Poland

Agnieszka Szcześniak [ASZ]

ORCID: 0009-0009-7949-0383

E-Mail: agnieszkaszczesniak05@gmail.com

Medical University of Silesia, Poniatowskiego 15, 40-055 Katowice, Poland

Weronika Matyja [WM]

ORCID: 0009-0002-1897-6338

E-Mail: matyjaweronika7@gmail.com

Medical University of Silesia, Poniatowskiego 15, 40-055 Katowice, Poland

***Corresponding Author:**

Aleksandra Syguda

E-mail: aleksandra.syguda28@gmail.com

Abstract

Background. Body mass index (BMI) remains the default screening tool for body composition in athletes, even though it was validated in sedentary populations and cannot distinguish muscle from fat.

Aim. To summarize current evidence on the limitations of BMI in athletic populations, focusing on both the misclassification of muscularity and the under-detection of Relative Energy Deficiency in Sport (RED-S), and their combined implications for athletic performance.

Material and methods. A narrative review was conducted using PubMed, Scopus and Google Scholar, covering studies published between 1997 and 2025 on BMI, body composition, RED-S and athletic performance.

Results. BMI misclassifies a substantial share of muscular athletes as overweight or obese despite normal body fat, while athletes with clinically significant low energy availability can present with unremarkable BMI. Nearly half of athletes across sports show low energy availability, which impairs endurance, coordination, judgment and explosive power. Whether RED-S constitutes a single coherent syndrome remains scientifically contested.

Conclusions. BMI alone is inadequate for assessing athlete health and performance risk in either direction; validated, multidimensional screening tools should replace it as the default standard.

Key words: body mass index; RED-S; low energy availability; athletic performance; body composition

1. Introduction

Body mass index (body mass in kilograms divided by height in metres squared) is still the most widely used surrogate marker of adiposity in clinical and public health practice [1]. The Belgian statistician Adolphe Quetelet devised it in the mid-nineteenth century while trying to characterize the "average man" statistically. His goal was to describe how body size is distributed across a population, not to assess any one person's body composition [2]. Despite that origin, BMI became the default screening tool for overweight and obesity worldwide. The World Health Organization sets the same cut-offs for every adult regardless of sex, age, or activity level: 25 kg/m² for overweight, 30 kg/m² for obesity [1]. It requires only two easily obtained measurements, no specialized equipment and essentially no cost. That is largely why it became the standard first-line assessment across medicine, sport science, and epidemiology. That simplicity comes at a real cost for populations whose bodies do not resemble the largely sedentary groups the index was built on. Athletes are the clearest case: because BMI cannot tell muscle from fat, people carrying a lot of lean mass end up classified as overweight or obese despite low actual body fat. A study of 622 male athletes across several sport disciplines shows just how large this gap can be. Standard WHO cut-offs labeled 23.8% of participants overweight and 3.7% obese, but direct measurement of body fat by DXA scan found only 3.1% and 0.8% actually met those categories. Agreement between the two systems was poor ($\kappa = 0.169$) [3]. The same research group proposed higher, athlete-specific cut-offs (BMI ≥ 28.2 kg/m² for overweight, ≥ 33.7 kg/m² for obesity) and these tracked measured body fat much better ($\kappa = 0.522$), suggesting the standard WHO thresholds simply were not built with this population in mind [3]. Elite performance data point to the same conclusion from another angle: among the world's top track and field athletes, BMI correlates strongly with sprint speed ($r = 0.71$) and the spread of BMI values narrows as performance rises, clustering around event-specific optima rather than any single universal number [4].

A separate, largely independent line of research tackles the opposite problem: energy deficiency in athletes. Low energy availability occurs when dietary energy intake fails to cover training costs once the energy needed for basic physiological function is subtracted. Sustained low energy availability sits at the center of what researchers in the 1990s named the Female Athlete Triad, a syndrome linking energy deficiency, menstrual dysfunction and weakened bone health in female athletes [5, 6]. The International Olympic Committee significantly expanded this framework in 2014, introducing Relative Energy Deficiency in Sport (RED-S) to cover a wider range of body systems and to include male and para-athletes

alongside women [7]. Its most recent consensus statement, from 2023, updated the terminology to "REDs" and introduced new models linking problematic energy availability to both health and performance outcomes [8].

BMI misclassification and RED-S are best understood as two sides of the same problem rather than separate research areas. Muscular athletes get pushed toward false-positive labels of overweight or obesity, while athletes running a genuine energy deficit can look entirely unremarkable on a BMI chart, letting a serious underlying condition slip past unnoticed. A study of competitive male runners shows this second pattern clearly: those with lower energy availability had measurably weaker skeletal integrity than non-athletic controls, even though body weight and BMI differed only modestly between the two groups [9]. Reviews of RED-S screening tools point to a related tension. High training energy expenditure and low body fat are simultaneously markers of athletic success and warning signs of energy deficiency, which limits how much body composition alone can tell you about whether a lean athlete is healthy or at risk [10]. So BMI can raise false alarms among muscular athletes while missing genuine risk among the energy-deficient, sometimes in the same population.

Both failures matter for more than a mislabeled chart entry. A meta-analysis pooling 59 studies and over 6,000 athletes found that 44.7% had low energy availability, and 63.0% of those specifically assessed for RED-S risk met the diagnostic criteria. Athletes with low energy availability performed measurably worse on running performance, endurance, training response, coordination, concentration, judgment, explosive power and agility than athletes at normal energy availability [11]. Experimental work backs up a causal reading: deliberately inducing low energy availability in trained endurance athletes under controlled conditions produced measurable drops in explosive power [12]. The misclassification side has drawn much less direct study, but plausible risks remain, including unnecessary dietary or training changes imposed on athletes who do not need them, plus the psychological weight of a body-composition label that does not match how an athlete's body actually functions.

Separate bodies of literature already cover BMI's limitations in athletes and the epidemiology, mechanisms and consequences of RED-S, including several recent reviews [11, 13]. To our knowledge, though, no one has treated these as two sides of one problem: BMI simply does not perform well across the range of physiques found in competitive sport and that failure carries performance consequences no matter which direction it points. The result is that coaches, sports physicians and athletes are left without a clear picture of when BMI can be trusted and when it actively gets in the way of sound assessment.

This narrative review sets out to summarize current evidence on the limitations of BMI as an assessment tool in athletic populations, focusing on its role in both the misclassification of muscularity and the under-detection of Relative Energy Deficiency in Sport (RED-S), and what both mean together for athletic performance.

2. Research Materials and Methods

This narrative review summarizes current evidence on the limitations of body mass index (BMI) as an assessment tool in athletic populations, focusing on the misclassification of muscularity, the under-detection of Relative Energy Deficiency in Sport (RED-S) and their combined implications for athletic performance. Relevant literature published in peer-reviewed journals, systematic reviews and meta-analyses, and International Olympic Committee consensus statements was identified through a non-systematic search of PubMed, Scopus and Google Scholar, covering publications from 1997 to 2025, with the majority published after 2014. The search targeted publications addressing body mass index, body composition, athlete misclassification, low energy availability, relative energy deficiency in sport, overtraining syndrome, and athletic performance outcomes across male and female athletes at recreational, collegiate and elite competition levels. Priority was given to recent systematic reviews, meta-analyses and validated assessment instruments, including the Low Energy Availability in Females Questionnaire (LEAF-Q) and the IOC Relative Energy Deficiency in Sport Clinical Assessment Tool (CAT2), alongside international consensus statements from sport medicine bodies such as the International Olympic Committee. Selected publications were analyzed narratively to provide an up-to-date overview of the prevalence, mechanisms, performance-related consequences and management approaches associated with BMI limitations and RED-S in athletic populations.

3. Research Results

3.1 BMI as an Assessment Tool in Athletic Populations

BMI remains the default first-line body-composition screen in sport science and clinical sports medicine, despite having been developed and validated in general, sedentary populations rather than athletes [3]. Applied without adjustment to athletes, this mismatch produces predictable errors. Among 622 male athletes across several sport disciplines in Italy, standard WHO cut-offs classified 23.8% as overweight and 3.7% as obese, while direct measurement of body fat via DXA found only 3.1% and 0.8% of the same group actually met those categories. Agreement between the two methods was poor ($\kappa = 0.169$). Revised, athlete-

specific cut-offs (≥ 28.2 kg/m² for overweight, ≥ 33.7 kg/m² for obesity) tracked measured adiposity far more closely ($\kappa = 0.522$) [3].

This is not confined to one study or sport: Table 1 summarizes comparable prevalence data on BMI misclassification and low energy availability across the range of athlete populations discussed throughout this review.

Table 1. Prevalence of BMI misclassification and low energy availability/RED-S across athlete populations

Population	Prevalence / Finding	Source
Male athletes (Italy, multi-sport)	23.8% overweight, 3.7% obese by WHO BMI; actual DXA: 3.1%, 0.8%	Milanese et al., 2025 [3]
Athletes (meta-analysis, 59 studies, n=6,118)	44.7% low energy availability; 63.0% RED-S risk among assessed	Gallant et al., 2025 [11]
Elite/pre-elite Australian female athletes	~80% with ≥ 1 RED-S symptom	Rogers et al., 2021 [14]
Malaysian national athletes	Elevated RED-S risk across sport types	Marzuki et al., 2023 [15]
Chinese elite/recreational female aesthetic athletes	Elevated RED-S risk	Meng et al., 2020 [16]
Female endurance athletes	8-56% risk range (method-dependent)	Fahrenholtz et al., 2022 [17]
Elite female sprinters	Meaningful indicators of LEA	Sygo et al., 2018 [18]
Kho-Kho players (India)	Comparable risk patterns to Western sports	Kalpana et al., 2023 [19]

Population	Prevalence / Finding	Source
Competitively trained male endurance athletes	Meaningful rates of LEA	Lane et al., 2019 [20]
Elite female Malaysian athletes	89.2% disordered eating, 47.6% menstrual irregularity	Quah et al., 2009 [21]

Studies are drawn from Sections 3.1 and 3.4 and illustrate both directions of assessment failure this review discusses: false-positive overweight/obesity classification under standard BMI thresholds [3] and the widespread, cross-sport prevalence of low energy availability and RED-S risk that BMI alone cannot detect [11, 14–21]. EA = energy availability; RED-S = Relative Energy Deficiency in Sport.

Among competitive athletes, BMI behaves less like a universal health threshold and more like a discipline-specific variable. Among the top 100 international male athletes across track and field events from 100 m to marathon, BMI correlated strongly with sprint speed ($r = 0.71$) and the direction of that relationship depended on event distance: a heavier, higher-BMI build favored sprinters, a lighter, lower-BMI build favored distance runners. As performance level rose within each event, the spread of athletes' BMI values narrowed, clustering around a distance-specific optimum rather than any single value one could call universally healthy [4]. Taken together, these findings suggest BMI performs poorly as a single screening threshold in athletic populations. It misreads adiposity in muscular athletes and no fixed "correct" BMI applies uniformly across sports and events anyway.

3.2 Mechanisms of BMI Misclassification in Athletes

Why this happens is straightforward: BMI reflects only total body mass relative to height and cannot distinguish muscle, fat, bone and water from one another. Resistance-trained and power-oriented athletes carry substantially more lean muscle than a sedentary person of the same height, so their body mass, and with it their BMI, rises without any matching increase in body fat. This has been documented across sport disciplines in male athletes [3].

The same mechanism explains why BMI's relationship to performance shifts from sport to sport instead of staying constant. Extra muscle mass helps in some events, such as sprinting, where a higher BMI tracks with faster speed, and hurts in others, like distance running, where

a lower BMI tracks with faster times. So both which BMI value is most likely to trigger misclassification, and which direction that misclassification runs, depend heavily on the event and sport in question. The narrowing of BMI variability at higher performance levels reflects the same selection pressure at work: athletes gravitate toward, and get selected for, whatever physique suits their event best, so their BMI clusters around a discipline-specific optimum that has nothing to do with the general-population thresholds the WHO uses [4].

3.3 Relative Energy Deficiency in Sport (RED-S): Definitions and Conceptual Evolution

RED-S covers the wide range of health and performance problems that flow from chronic low energy availability: dietary intake that fails to cover the real energy cost of training once basic physiological needs are subtracted. The concept has gone through several iterations since it was first named. The American College of Sports Medicine's original 1997 position stand described the Female Athlete Triad: disordered eating or low energy availability, menstrual dysfunction, and low bone mineral density, specifically in female athletes [5]. A 2007 update sharpened the diagnostic criteria and reframed each component of the triad as sitting on a continuum of severity rather than a simple present-or-absent state [6].

The IOC broadened the model considerably in 2014, introducing RED-S to extend the concept beyond the original three-component triad, covering immune, cardiovascular, gastrointestinal, endocrine, and psychological function, and beyond female athletes, to include men and para-athletes [7]. Its 2023 consensus statement updated both the model and its name to "REDs," introduced Health and Performance Conceptual Models placing low energy availability on a continuum from adaptable to problematic, and formalized a structured clinical tool, the IOC REDs CAT2, for screening, risk stratification, and diagnosis [8, 22].

3.4 Prevalence of RED-S and Low Energy Availability Across Sports

Low energy availability turns out to be common rather than rare among athletes and a growing body of primary research backs this up. A meta-analysis of 59 studies covering 6,118 athletes found that 44.7% (2,737 athletes) had low energy availability (44.2% of the women, 49.4% of the men), while 63.0% of those specifically assessed for RED-S risk (460 of 730, across eight studies) met the criteria for concern [11]. These comparable, if anything slightly higher, rates among men push back against the older assumption that low energy availability is mainly a female athlete's problem, a pattern echoed in dedicated studies of male endurance athletes, which report meaningful rates of their own [20].

Prevalence varies a lot by sport and setting. Among elite and pre-elite female Australian athletes, roughly four in five showed at least one symptom consistent with RED-S [14]. An earlier study of elite female Malaysian athletes in lean, aesthetically demanding sports found

strikingly high rates of disordered eating (89.2%), plus elevated menstrual irregularity (47.6%) and poor bone quality (13.3%) [21]; a more recent national cross-sectional study confirmed that RED-S risk remains elevated among Malaysian national athletes across sport types [15]. Aesthetic sports generally carry elevated risk, as seen among Chinese elite and recreational female athletes in aesthetically oriented disciplines [16], while female endurance athletes show a wide reported range of 8% to 56%, depending on which assessment method is used [17]. Risk is not confined to lean or endurance sports, either: elite female sprinters, whose physique and event demands differ substantially from distance runners, show meaningful indicators of low energy availability too [18] and less commonly studied sports outside Western contexts, such as Kho-Kho in India, show comparable risk patterns [19]. Low energy availability and RED-S risk, then, show up across sport types, competition levels, sexes and regions, not just among the female endurance and aesthetic-sport athletes who dominate the classic literature on this subject.

3.5 Mechanisms Linking Low Energy Availability to Performance

Low energy availability seems to hurt performance through several physiological mechanisms working together rather than any single pathway. In the largest pooled analysis available, Gallant et al. [11] found that athletes with low energy availability performed worse on running performance, training response, endurance, coordination, concentration, judgment, explosive power, and agility than athletes at normal energy availability, and missed training due to illness more often. Most of this evidence comes from observational and cross-sectional comparisons, which establish association more firmly than causation.

Experimental work helps close that gap. In a controlled trial, deliberately lowering energy availability in trained male endurance athletes over a set period produced a measurable drop in explosive power relative to athletes kept in energy balance, direct evidence that reduced energy availability degrades this specific capacity rather than just accompanying it [12]. Surrogate markers of low energy availability, including menstrual disturbance and a suppressed resting metabolic rate, correlate with both the health and performance consequences the RED-S model predicts, which lends some support to RED-S as a coherent framework linking energy status to function [23].

One mechanism proposed specifically for male athletes involves testosterone: chronic energy deficiency suppresses its production, and researchers have suggested this hormonal disruption as a pathway connecting low energy availability to reduced strength, power, and overall performance in male endurance athletes [24]. Over a longer time horizon, low energy availability also erodes skeletal health. Reviews note that its effects on bone are hard to pick

up with simple assessment tools, yet they carry a disproportionate impact on bone stress injury rates among elite distance athletes, a slower-developing performance threat that works through accumulated injury risk rather than any single acute decline [25].

Table 2. Effects of low energy availability on physical and cognitive performance domains

Performance Domain	Effect of LEA	Evidence Type
Endurance	↓ Performance	Observational pooling [11]
Explosive Power	↓ Performance	Experimental induction [12]
Coordination	↓ Performance	Observational pooling [11]
Concentration	↓ Performance	Observational pooling [11]
Judgment	↓ Performance	Observational pooling [11]
Training Response	↓ Adaptation	Observational pooling [11]
Bone Health	↓ Skeletal integrity	Observational [9, 25]
Illness Risk	↑ Missed training	Observational pooling [11]

Effects span acute performance capacities (endurance, explosive power, coordination), longer-term structural outcomes (bone health), and training availability, with evidence ranging from large-scale observational pooling [11] to controlled experimental induction of low energy availability [12]. LEA = low energy availability.

3.6 The BMI Blind Spot: Normal BMI Does Not Exclude RED-S

Section 3.1 covered how BMI over-flags muscular athletes as overweight or obese. The opposite failure matters just as much: an athlete running a genuine energy deficit can show up with entirely ordinary body weight and BMI, letting a serious underlying problem go unnoticed by body-composition screening alone. A study of competitive male distance runners makes this concrete: those with lower energy availability had measurably weaker skeletal integrity than non-athlete controls, even though most of the runners were not

underweight and body weight differed only modestly between groups [9]. But routine BMI-based screening is unlikely to catch this kind of skeletal impairment, since BMI simply cannot capture the underlying metabolic state driving it.

This blind spot follows directly from what makes an athlete good at their sport in the first place. High training energy expenditure and low body fat are, at the same time, markers of peak performance and warning signs of energy deficiency, according to reviews of RED-S screening tools. That means body composition alone cannot reliably tell a lean, healthy, high-performing athlete from a lean, energy-deficient, at-risk one [10]. The broader difficulty of measuring energy availability accurately in the field, discussed further in Section 3.5, makes this worse: even purpose-built energy availability assessments have their own methodological limits, and a simple weight-and-height proxy like BMI is much less capable than these already-imperfect tools of capturing the underlying physiology [25].

3.7 Overlap with Overtraining Syndrome

Low energy availability does not happen independently of an athlete's training load. The two interact closely and each seems able to make the other worse. In a controlled study of female runners, experimentally lowering energy availability during a period of heavy training was directly linked to non-functional overreaching (a maladaptive overtrained state with slow recovery) along with suppressed ovarian function [26]. Energy deficiency and overtraining dysfunction are mechanistically tangled together rather than independent problems: an athlete pushing through a heavy training block without adequate nutrition can develop features of both RED-S and overtraining syndrome simultaneously, each worsening the other. That matters for BMI-based screening in particular, because an athlete in this combined state may show no body-composition signature BMI could ever pick up, deepening the blind spot described in Section 3.6.

3.8 Screening and Assessment Tools Beyond BMI

Given BMI's failures in both directions, researchers have built alternative screening tools specifically for athletes. The Low Energy Availability in Females Questionnaire (LEAF-Q) was among the first, designed to flag female athletes at risk for the Triad using self-reported symptoms across injury history, gastrointestinal function and reproductive function rather than anthropometry [27]. A later review of thirteen such questionnaires found that LEAF-Q remains the most widely used validated option, but also flagged a structural gap: roughly half its items concern menstrual function, which makes it unsuitable for male athletes and leaves this population without an equivalent validated tool [10].

Table 3. Comparison of body-composition and energy-availability assessment tools available for athletic populations

Tool	Type	Population	Strength	Limitation
BMI	Anthropometric proxy	General	Quick, cheap, no equipment	Cannot distinguish fat from muscle; athlete-specific thresholds needed [3]
Athlete-adjusted BMI	Anthropometric proxy	Athletes	Better tracks adiposity in athletes [3]	Still a single-number proxy; does not capture energy status
Skinfolds	Anthropometric	General/Athletes	Directly estimates body fat percentage	Requires trained assessor; inter-rater variability
DXA	Imaging	General/Athletes	Gold-standard body composition	Expensive, limited access, radiation exposure
LEAF-Q	Symptom questionnaire	Female athletes	Validated; captures RED-S risk [27]	Not validated for male athletes [10]
IOC REDs	Multi-step clinical tool	All athletes	Comprehensive; includes	Resource-intensive;

Tool	Type	Population	Strength	Limitation
CAT2			screening, risk stratification, diagnosis [22]	requires clinical training

Ordered from least to most clinically comprehensive. The table captures this review's central argument: standard and even athlete-adjusted BMI remain single-number proxies [3], while validated symptom-based and multi-step clinical tools [22, 27] capture a broader, more athlete-relevant risk profile at the cost of greater complexity or resource requirements. DXA = dual-energy X-ray absorptiometry; LEAF-Q = Low Energy Availability in Females Questionnaire; CAT2 = Clinical Assessment Tool, Version 2.

At the level of formal clinical practice, the IOC has folded these elements into a structured protocol. The REDs Clinical Assessment Tool, Version 2 (CAT2), works through three steps (screening, severity and risk stratification, and clinical diagnosis and treatment) and treats body composition and anthropometry as just one input among several, alongside physiological, behavioral, and psychological indicators [22]. Unlike BMI-only screening, CAT2 never bases a diagnosis on a single anthropometric value.

3.9 Prevention and Intervention Strategies

Preventing and managing RED-S-related risk means looking well beyond body composition. Mental health and RED-S intersect closely: psychological factors can precede energy deficiency or result from it, a relationship the 2023 IOC consensus process considered important enough to warrant its own dedicated narrative review [28]. That has a direct clinical implication: because disordered eating so often accompanies or drives low energy availability, treating an affected athlete calls for sport-specific adaptation rather than an unmodified, generic eating-disorder protocol [29].

Qualitative accounts from athletes living with RED-S reinforce the case for a multidisciplinary approach that does not lean on body composition. A qualitative study of lightweight rowers found that many athletes kept hitting their competition weight targets while experiencing serious physiological and psychological distress underneath, a real-world illustration of the blind spot described in Section 3.6 [30]. No single intervention covers this problem on its own. Energy availability monitoring, validated symptom-based screening,

mental health support, and sport-specific clinical expertise all need to work together; periodic BMI checks alone were never going to catch this kind of risk.

4. Discussion

The evidence gathered here shows BMI failing athletes in two opposite directions at once. Standard WHO thresholds mislabel a large share of muscular athletes as overweight or obese despite normal or low body fat [3] while athletes with clinically meaningful energy deficiency can present with entirely unremarkable BMI values, letting real physiological risk go unnoticed [9]. Low energy availability itself is common rather than rare: close to half of athletes across sport types meet criteria for LEA, and a majority of those assessed for RED-S risk meet diagnostic thresholds [11]. Both directions of BMI failure carry performance costs. Energy deficiency measurably impairs endurance, coordination, judgment and explosive power, and experimental work supports a causal rather than merely correlational relationship [12]. Going the other way, an athlete wrongly flagged as overweight risks unnecessary dietary or training changes forced onto a body that does not need them. The field now has tools better suited than BMI for catching both problems, from LEAF-Q [27] to the IOC's three-step CAT2 protocol [22], though none of these is without its own limitations.

Readers should know that the RED-S framework itself is currently under direct challenge, in a debate playing out in the same journal that houses the IOC consensus statements. Jeukendrup and colleagues argue that energy availability, the variable at the center of the RED-S model, cannot be measured accurately enough in field settings to support a diagnosis and propose that what gets labeled "RED-S" more likely reflects at least eight distinct underlying causes rather than one unifying deficiency [31]. The IOC consensus group responded within months, defending the model's coherence and clinical usefulness [32]. Jeukendrup's group then replied again, maintaining that empirical support for RED-S as a single syndrome is still thin [33]. Qualitative work with athletes adds another layer: lightweight rowers describe living with symptoms consistent with RED-S while still hitting their competition weight targets, which suggests lived experience does not map cleanly onto any one diagnostic model, whichever side of the debate you find convincing [30]. None of this undermines the central argument of this review. Both sides of the RED-S debate agree that body-composition measures, BMI included, cannot capture energy availability status. Where they disagree is over what should replace BMI as the unifying framework, not over whether BMI itself is up to the job.

Two practical shifts follow from this evidence. First, an elevated BMI in a muscular athlete should trigger a body-composition check (skinfolds, DXA, or similar) before any dietary or

training intervention, given how weakly BMI actually tracks adiposity in this population [3]. Second, a normal BMI should not be read as reassurance that an athlete is free of energy-related risk, particularly for male athletes and for sports outside the classically studied endurance and aesthetic categories, where screening tools remain underdeveloped [10]. Screening built around CAT2 or validated questionnaires, combined with routine attention to training load, menstrual history where relevant and mental health, offers a far more defensible starting point than BMI checks alone [22, 28]. Given the live dispute over what RED-S actually is, clinicians may do better treating any single diagnostic label with some caution and leaning instead on the underlying, better-established findings: energy deficiency impairs performance and bone health, whatever name gets attached to the syndrome.

Several gaps qualify these conclusions. The literature on BMI misclassification and the literature on RED-S prevalence developed as largely separate fields, studied by different research groups using different methods. This review brings them together conceptually, but few if any individual studies measure both phenomena in the same athletes, so the two-sided "blind spot" argument rests on inference across studies rather than evidence within a single study. Much of the RED-S prevalence literature also still concentrates on female and endurance athletes, leaving male athletes and power, team and weight-class sports comparatively under-studied [20], a gap partly reflected in the LEAF-Q's own structural exclusion of male-relevant symptoms [10]. Most prevalence estimates come from cross-sectional designs, which limits causal inference outside the handful of experimental studies such as Jurov et al. [12]. Finally, the ongoing dispute over whether energy availability can be measured reliably in the field at all [31] is itself worth taking seriously as a limitation. If the core exposure variable in RED-S research resists accurate field measurement, then the prevalence figures cited throughout this review, including the headline 44.7% LEA estimate [11], are best read as estimates built on an imperfect measurement foundation, not as precise counts.

5. Conclusions

BMI is still treated as a quick, reliable snapshot of an athlete's health but the evidence gathered here says otherwise. It mislabels muscular athletes as overweight or obese often enough to matter: agreement between BMI and actual body fat in male athletes barely beats chance [3]. It also misses genuine problems at the other end just as often, letting energy-deficient athletes look unremarkable on paper while their bones and hormones say otherwise

[9]. Neither failure is a rare edge case: close to half of athletes across sports show some degree of low energy availability [11], a condition BMI was never built to detect.

Both failures spill over from classification into performance. Energy deficiency measurably impairs endurance, coordination, judgment, and explosive power, and at least one controlled trial supports a causal rather than merely correlational relationship [12]. Wrongly flagging a well-muscled athlete as overweight has its own costs too, including unnecessary dietary and training changes that have nothing to do with how that athlete actually performs. Whether these two failure modes trace back to one underlying measurement problem or several is itself disputed, in an exchange between Jeukendrup and Mountjoy's groups that is still ongoing [31, 32]; either way, the practical upshot is the same: BMI alone cannot give coaches or physicians the information they need.

Better tools already exist. LEAF-Q, the IOC's CAT2 protocol and direct body-composition measurement should replace BMI as the default assessment, not sit alongside it as an afterthought [22]. What the field still lacks is research examining both sides of this problem in the same athletes, rather than treating misclassification and RED-S as separate literatures that happen to address a common issue. Male athletes and power, team, and weight-class disciplines remain comparatively understudied next to female endurance athletes [20] and the dispute over whether energy availability can be measured accurately in the field [31] needs resolving before prevalence figures in this area can be treated as more than reasonable estimates. Until then, coaches and clinicians are better off treating BMI as a preliminary flag that calls for further evaluation, not as a definitive assessment.

Disclosures

The authors report no disclosures.

Author Contributions

Conceptualization: AS, ASZ;

Methodology: AS, ASZ;

Software: not applicable;

Check: AS, WM, KT;

Formal analysis: AS;

Investigation: AS, KT, AST;

Resources: AS, AST;

Data curation: AS, ASZ, WM;

Writing – Original Draft Preparation: AS, KT, AST;

Writing – Review and Editing: AS;

Visualisation: AS;

Supervision: WM;

Project administration: AS;

Receiving funding: Not applicable – no specific funding.

All authors have read and agreed with the published version of the manuscript.

Funding Statement

The study did not receive external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Acknowledgments

Not applicable.

Conflicts of Interest

The authors declare no conflicts of interest.

Declaration of the Use of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT for the purpose of language editing and stylistic refinement to improve clarity and readability of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the accuracy, integrity and conclusions of the publication.

References

1. WHO (2025) World Health Organization. Obesity and overweight 2025. <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>
2. Eknayan G (2008) Adolphe Quetelet (1796-1874) - The average man and indices of obesity. *Nephrology Dialysis Transplantation* 23:47–51. <https://doi.org/10.1093/NDT/GFM517>
3. Milanese C, Itani L, Cavedon V, et al (2025) Revising BMI Cut-Off Points for Overweight and Obesity in Male Athletes: An Analysis Based on Multivariable Model-Building. *Nutrients* 17. <https://doi.org/10.3390/NU17050908>
4. Sedeaud A, Marc A, Marck A, et al (2014) BMI, a performance parameter for speed improvement. *PLoS One* 9. <https://doi.org/10.1371/JOURNAL.PONE.0090183>
5. Otis CL, Drinkwater B, Johnson M, et al (1997) ACSM position stand: The Female Athlete Triad. *Med Sci Sports Exerc* 29. <https://doi.org/10.1097/00005768-199705000-00037>
6. Nattiv A, Loucks AB, Manore MM, et al (2007) The female athlete triad. *Med Sci Sports Exerc* 39:1867–1882. <https://doi.org/10.1249/MSS.0B013E318149F111>
7. Mountjoy M, Sundgot-Borgen J, Burke L, et al (2014) The IOC consensus statement: Beyond the Female Athlete Triad-Relative Energy Deficiency in Sport (RED-S). *Br J Sports Med* 48:491–497. <https://doi.org/10.1136/BJSPORTS-2014-093502>
8. Mountjoy M, Ackerman KE, Bailey DM, et al (2023) 2023 International Olympic Committee's (IOC) consensus statement on Relative Energy Deficiency in Sport (REDs). *Br J Sports Med* 57:1073–1097. <https://doi.org/10.1136/BJSPORTS-2023-106994>
9. Haines MS, Kaur S, Scarff G, et al (2023) Male Runners With Lower Energy Availability Have Impaired Skeletal Integrity Compared to Nonathletes. *Journal of Clinical Endocrinology and Metabolism* 108:e1063–e1073. <https://doi.org/10.1210/CLINEM/DGAD215>
10. Sim A, Burns SF (2021) Review: questionnaires as measures for low energy availability (LEA) and relative energy deficiency in sport (RED-S) in athletes. *J Eat Disord* 9. <https://doi.org/10.1186/S40337-021-00396-7>
11. Gallant TL, Ong LF, Wong L, et al (2025) Low Energy Availability and Relative Energy Deficiency in Sport: A Systematic Review and Meta-analysis. *Sports Medicine* 55:325–339. <https://doi.org/10.1007/S40279-024-02130-0>

12. Jurov I, Keay N, Spudić D, Rauter S (2022) Inducing low energy availability in trained endurance male athletes results in poorer explosive power. *Eur J Appl Physiol* 122:503–513. <https://doi.org/10.1007/S00421-021-04857-4>
13. Logue DM, Madigan SM, Melin A, et al (2020) Low energy availability in athletes 2020: An updated narrative review of prevalence, risk, within-day energy balance, knowledge, and impact on sports performance. *Nutrients* 12. <https://doi.org/10.3390/NU12030835>
14. Rogers MA, Appaneal RN, Hughes D, et al (2021) Prevalence of impaired physiological function consistent with Relative Energy Deficiency in Sport (RED-S): An Australian elite and pre-elite cohort. *Br J Sports Med* 55:38–45. <https://doi.org/10.1136/BJSPORTS-2019-101517>
15. Marzuki MIH, Mohamad MI, Chai WJ, et al (2023) Prevalence of Relative Energy Deficiency in Sport (RED-S) among National Athletes in Malaysia. *Nutrients* 15. <https://doi.org/10.3390/NU15071697>
16. Meng K, Qiu J, Benardot D, et al (2020) The risk of low energy availability in Chinese elite and recreational female aesthetic sports athletes. *J Int Soc Sports Nutr* 17. <https://doi.org/10.1186/S12970-020-00344-X>
17. Fahrenholtz IL, Melin AK, Wasserfurth P, et al (2022) Risk of Low Energy Availability, Disordered Eating, Exercise Addiction, and Food Intolerances in Female Endurance Athletes. *Front Sports Act Living* 4. <https://doi.org/10.3389/FSPOR.2022.869594>
18. Sygo J, Coates AM, Sesbreno E, et al (2018) Prevalence of indicators of low energy availability in elite female sprinters. *Int J Sport Nutr Exerc Metab* 28:490–496. <https://doi.org/10.1123/IJSNEM.2017-0397>
19. Kalpana K, Cherian KS, Khanna GL (2023) Energy availability and RED-S risk assessment among Kho-Kho players in India. *Sport Sci Health* 19:1101–1108. <https://doi.org/10.1007/S11332-022-00996-Z>
20. Lane AR, Hackney AC, Smith-Ryan A, et al (2019) Prevalence of low energy availability in competitively trained male endurance athletes. *Medicina (Lithuania)* 55. <https://doi.org/10.3390/MEDICINA55100665>
21. Quah YV, Poh BK, Ng LO, Noor MI (2009) The female athlete triad among elite Malaysian athletes: prevalence and associated factors. *Asia Pac J Clin Nutr* 18:200–8
22. Stellingwerff T, Mountjoy M, McCluskey WTP, et al (2023) Review of the scientific rationale, development and validation of the International Olympic Committee Relative Energy Deficiency in Sport Clinical Assessment Tool: V.2 (IOC REDs CAT2) - By a

- subgroup of the IOC consensus on REDs. *Br J Sports Med* 57:1109–1118. <https://doi.org/10.1136/BJSPORTS-2023-106914>
23. Ackerman KE, Holtzman B, Cooper KM, et al (2019) Low energy availability surrogates correlate with health and performance consequences of Relative Energy Deficiency in Sport. *Br J Sports Med* 53:628–633. <https://doi.org/10.1136/BJSPORTS-2017-098958>
 24. Cupka M, Sedliak M (2023) Hungry runners – low energy availability in male endurance athletes and its impact on performance and testosterone: mini-review. *Eur J Transl Myol* 33. <https://doi.org/10.4081/EJTM.2023.11104>
 25. Heikura IA, Uusitalo ALT, Stellingwerff T, et al (2018) Low energy availability is difficult to assess but outcomes have large impact on bone injury rates in elite distance athletes. *Int J Sport Nutr Exerc Metab* 28:403–411. <https://doi.org/10.1123/IJSNEM.2017-0313>
 26. Schaal K, VanLoan MD, Hausswirth C, Casazza GA (2021) Decreased energy availability during training overload is associated with non-functional overreaching and suppressed ovarian function in female runners. *Appl Physiol Nutr Metab* 46:1179–1188. <https://doi.org/10.1139/APNM-2020-0880>
 27. Melin A, Tornberg ÅB, Skouby S, et al (2014) The LEAF questionnaire: A screening tool for the identification of female athletes at risk for the female athlete triad. *Br J Sports Med* 48:540–545. <https://doi.org/10.1136/BJSPORTS-2013-093240>
 28. Pensgaard AM, Sundgot-Borgen J, Edwards C, et al (2023) Intersection of mental health issues and Relative Energy Deficiency in Sport (REDs): A narrative review by a subgroup of the IOC consensus on REDs. *Br J Sports Med* 57:1127–1135. <https://doi.org/10.1136/BJSPORTS-2023-106867>
 29. Conviser JH, Schlitzer Tierney A, Nickols R (2018) Essentials for best practice: treatment approaches for athletes with eating disorders. *J Clin Sport Psychol* 12:495–507. <https://doi.org/10.1123/JCSP.2018-0013>
 30. Gillbanks L, Mountjoy M, Filbay SR (2022) Lightweight rowers' perspectives of living with Relative Energy Deficiency in Sport (RED-S). *PLoS One* 17. <https://doi.org/10.1371/JOURNAL.PONE.0265268>
 31. Jeukendrup AE, Areta JL, Van Genechten L, et al (2024) Does Relative Energy Deficiency in Sport (REDs) Syndrome Exist? *Sports Medicine* 54:2793–2816. <https://doi.org/10.1007/S40279-024-02108-Y>

32. Mountjoy ML, Ackerman KE, Bailey DM, et al (2025) Yes: Relative Energy Deficiency in Sport (REDs) Does Exist! *Sports Medicine* 55:2045–2049. <https://doi.org/10.1007/S40279-025-02219-0>
33. Areta JL, Jeukendrup AE, Van Genechten L, et al (2025) Limited Empirical Support for Relative Energy Deficiency in Sport (REDs) Syndrome. *Sports Medicine* 55:2051–2055. <https://doi.org/10.1007/S40279-025-02220-7>