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Best practice recommendations for body composition considerations in sport to reduce health and performance risks: a critical review, original survey and expert opinion by a subgroup of the IOC consensus on Relative Energy Deficiency in Sport (REDs)

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ABSTRACT

Background The assessment of body composition (BC) in sport raises concern for athlete health, especially where an overfocus on being lighter or leaner increases the risk of Relative Energy Deficiency in Sport (REDs) and disordered eating.

Methods We undertook a critical review of the effect of BC on performance (29 longitudinal, prospective or intervention studies) and explored current practice related to BC considerations via a follow-up to a 2013 internationally distributed survey.

Results The review found that a higher level of body fat was negatively associated with endurance performance, while a gain in muscle mass resulted in performance benefits across sports. BC did not contribute to early talent identification, and no unique cut-off to signify a performance advantage for BC was identified. BC appears to be one of an array of variables impacting performance, and its influence should not be overstated. The survey (125 practitioners, 61 sports and 26 countries) showed subtle changes in BC considerations over time, such as an increased role for sport dietitian/nutrition practitioners as BC measurers (2013: 54%, 2022: 78%); less emphasis on reporting of body fat percentage (2013: 68%, 2022: 46%) and reduced frequency of BC assessment if ≥every fourth week (2013: 18%, 2022: 5%). Respondents remained concerned about a problematic focus on BC (2013: 69%, 2022: 78%). To address these findings, we provide detailed recommendations for BC considerations, including an overview of preferable BC methodology.

Conclusions The 'best practice' guidelines stress the importance of a multidisciplinary athlete health and performance team, and the treatment of BC data as confidential medical information. The guidelines provide a health focus around BC, aiming to reduce the associated burden of disordered eating, problematic low energy availability and REDs.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ It is presumed that body composition (BC) directly affects sports performance and that elite athletes should be muscular and lean, yet a comprehensive review of the literature examining this assumption has not been done.

⇒ An overemphasis on the importance of BC for sports performance and frequent BC assessments may promote body dissatisfaction, body image disturbance and eating and training behaviour that results in problematic low energy availability and symptoms of REDs.

WHAT THIS STUDY ADDS

⇒ This critical literature review has identified that research on the presumed association between BC and competitive success is preliminary and focused primarily on endurance sports. Increase in muscle mass relate to favourable performance outcomes across sports more consistently than low body fat mass.

⇒ The survey finds that practitioners remain concerned about the impact of the focus on BC as it may affect athletes' well-being. Encouragingly, practices are evolving, with greater compliance to best practice protocols, including less frequent assessments.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The introduction of 'best practice' recommendations for BC considerations in sport responds to a much-needed paradigm shift, that is, an intentional shift away from any potential harmful practice to a more considered, interdisciplinary process for BC assessment and management. The recommendations provide professional guidelines beyond the process of assessment alone, inclusive of assessment justification, consent, method selection, data capture and interpretation, reporting and appropriate communication and monitoring.

INTRODUCTION

In many sports, there is a desire to achieve an 'ideal' body mass (BM) or composition (BC) for competitive success, with characteristics varying according to the demands of the sport, and possibly the specific position or role within a sport. Such evidence is typically based on cross-sectional analysis of heterogeneous groups of athletes within a sport and reinforced by studies of the typical physical characteristics of elite competitors.[1–5] Additionally, many sports are considered to be 'weight sensitive',[6] targeting low BM and leanness to aid performance. This may maximise effective BM within body weight categories, increase power to mass ratios, increase work efficiency, enhance gravitational and rotational movement of the body or obtain a sport-specific aesthetic.[3 7–10] A strategic, periodised short-term phase of energy deficit within an annual training programme with the guidance of an experienced sport dietitian/nutritionist and/or physiologist and sports medicine physician may be a necessary stimulus to achieve appropriate reductions in BM/body fat for peak performance.[11] However, the strength of the association between performance and a specific BC is limited by the lack of systematic investigation across sports, use of valid and comparable methodology and standardised test protocols, and the paucity of longitudinal interventions confirming the impact of BC manipulation on performance.[2 6]

A focus on the perceived optimal BC of athletes may mislead athletes, coaches and the athlete's health and performance team to overly rely on physical appearance and build as performance determinants. This may lead to the implementation of interventions to adjust BM or BC, regardless of the genetic potential, sex, age, ethnicity, sport and specific position, performance level, health status and presenting BC of the individual athlete. Additionally, according to societal ideals of physique perceptions of athletes, or expectations within the sport (originating from the coaches, teammates, parents or sport culture), athletes may experience pressure to attain a certain lean 'athletic look'.[12–18] This may be further exacerbated by sporting attire, which may increase athletes' awareness of their physique.[13 16 19] A perceived pressure by athletes to reduce BM/body fat persistently or without appropriately considered justification may be associated with body dissatisfaction and symptoms of disordered eating (DE) and eating disorders (EDs)[17 20–22] and is also associated with allegations of physical and psychological abuse.[23] The inappropriate setting of BC goals related to low BM and body fat levels, even in the absence of psychological distress, can lead to problematic low energy availability (LEA) exposure and the subsequent development of relative energy deficiency in sport (REDs) (see definitions of LEA and REDs in box 1, cited from Mountjoy *et al*).[24] This is of concern specifically for youth athletes, who are at high risk for malnutrition, hormonal disturbances, disruption of growth and development and psychological impairment.[25 26] Therefore, there is a need to promote safe and evidence-based practices that address the total BC considerations process, specifically *why* (rationale) and *when* (screened and consented, timing and frequency) it is appropriate to assess BC, *who* (health and performance team) decides and performs the assessment and subsequent follow-up, *how* (method and procedure) this is conducted, and to *whom* results are communicated. On this basis, a discussion within the health and performance team may also be warranted to decide whether any BC manipulation is justified.

Health literacy and potential consequences from an overt focus on BC

Subelite athletes report coaches and social media as their most frequent sources for dietary information, with registered sports dietitian/nutritionists being an unlikely resource for these athletes.[27] Both the scientific literature and media document cases of abusive communication by coaches to athletes regarding BM and BC manipulation.[23 28–30] The unhealthy culture around BC is compounded among coaches and other professional members of the sport team by a lack of guidance around language, inadequate communication skills and a lack of established protocols on how to safely discuss BM and BC. Faced

Box 1 Terminology explained

Athlete health and performance team
A multidisciplinary support team, including as a minimum; a qualified, experienced sports dietitian/nutritionist, sports physiologist/strength coach, psychologist and sports medicine physician.

Body composition assessment
Refers to the measurement of body composition and the associated activities that are required for body composition measurements to be conducted (also see stage 2–4 in figure 1).

Body composition considerations
An umbrella term that refers to a holistic and collaborative approach that addresses aspects related to body composition practices, which is inclusive of various stakeholders including the athlete, coach, health and performance team, and where required; administrators within the organisation. Body composition assessment forms part of body composition considerations; a dynamic term to highlight that there may be further considerations to make in the future (also see stage 1–8 in figure 1).

Low energy availability (LEA)
LEA is any mismatch between dietary energy intake and energy expended in exercise that leaves the body's total energy needs unmet, i.e., there is inadequate energy to support the functions required by the body to maintain optimal health and performance. Low energy availability occurs as a continuum between scenarios in which effects are benign (adaptable LEA) and others in which there are substantial and potentially long-term impairments of health and performance (problematic LEA).

Problematic LEA
Problematic LEA is exposure to LEA that is associated with greater and potentially persistent disruption of various body systems, often presenting with signs and/or symptoms and represents a maladaptive response. The characteristics of problematic LEA exposure (e.g., duration, magnitude, frequency) may vary according to the body system and the individual. They may be further affected by interaction with moderating factors that can amplify the disruption to health, well-being and performance.

Relative Energy Deficiency in Sports
A syndrome of impaired physiological and/or psychological functioning experienced by female and male athletes that is caused by exposure to problematic (prolonged and/or severe) LEA. The detrimental outcomes include, but are not limited to, decreases in energy metabolism, reproductive function, musculoskeletal health, immunity, glycogen synthesis and cardiovascular and haematological health, which can all individually and synergistically lead to impaired well-being, increased injury risk, and decreased sports performance.

with direct or indirect encouragement by coaches to regulate BM by extreme methods,[25 28 30] athletes appear to lack knowledge of healthy BM regulation and the potential adverse effects of unhealthy methods.[31–34] Poor knowledge around sport-specific energy needs and the symptoms and consequences of problematic LEA exists among athletes, coaches and athletes' health and performance team, highlighting the need for increased awareness.[23 35–42] Some educational initiatives have been successful in increasing knowledge among athletes on causes and consequences of problematic LEA[43] and improved recognition by trainers of these issues.[36 41] This supports the need for more comprehensive and diverse coaching education, and specific inclusion of these themes within sport and exercise studies. Education must expand the knowledge and skills of coaches on their role regarding BC considerations, including the ability to safely integrate physique-related issues into coaching practice. Furthermore, it is important to establish formal protocols relating to BC considerations within sport organisations. This should include continuing education for the athlete health and performance team (see definition in box 1) and sports administrators (e.g., athletic directors, team leaders); an activity which currently does not appear to be routinely implemented.[23 36 37 40] However, as education may not be enough to motivate necessary changes in culture, priority and policy, other measures may also need to be considered, including international changes to rules/regulations within sport.[6 44–47]

Ten years ago, an ad hoc working group appointed by the International Olympic Committee highlighted the need to provide guidelines for BC considerations, including assessment methods, communicating and safety procedures.[6] The need for managing data safety was underscored by findings from a survey on BC assessment practices.[48] It is timely to re-evaluate current practice relating to BC considerations. The aims of this paper are three-fold: to (1) address current knowledge on the relationship between BC and performance in athletes of different ages and sports by conducting a critical review; (2) survey the evolution of BC considerations in sport internationally over the last 10 years and (3) provide best practice recommendations for BC considerations to prevent potential health and performance consequences of REDs.

METHODS

Critical review on BC and effect on performance

A comprehensive review was conducted in PubMed during August 2022 and repeated in December 2022, aiming to identify literature exploring the impact of athletes' BC on performance outcomes. For details on the search, see online supplemental material.[49] Athlete performance level and taxonomy of sport were characterised according to previous recommendations.[50]

Survey on BC practices

To assess current BC practices of practitioners across competitive sports, an electronic questionnaire was developed and circulated via social media and email lists (see questionnaire in online supplemental material). The questionnaire was based on a previous survey published 10 years ago.[6 48] Relevant results from the survey are presented in this paper and compared with the previous survey. For details on methodology and respondents for this survey, please see online supplemental material.

Equity, diversity and inclusion statement

In each process of this work, equity, diversity and inclusion have been considered, including composition of the project group (mixed genders, professions and positions) and analytical and scientific work and focus. The latter has been attained by recruiting survey-participants globally and digitally to overcome geographical distances or participation or access to specific settings or environments, or by doing a literature search, including athletes independent of individual identity. Furthermore, findings are presenting according to sex, age, ethnicity, culture or nations when applicable, and suggested guidelines take similar considerations when relevant.

RESULTS

Critical review on BC and effect on performance

The 29 studies identified in the comprehensive review (see online supplemental table 1) included interventional projects (n=12), longitudinal studies (n=7) and prospective evaluation of variables that predict performance in a sporting event (n=10). Most participants were highly trained adult athletes or talented young athletes (i.e., tier 2–3), primarily from endurance/long distance (n=14), team (n=5) and combat/weight-making (n=3) sports. While indices of body fat (ie, body fat mass, body fat percentage by dual-energy X-ray absorptiometry (DXA), skin fold thickness) were negatively associated with performance variables like race time in prolonged endurance events[51–57] or average speed in some team sports, training variables (eg, training volume and speed) or previous performance results achieved were either of equal[56 57] or greater importance[52–54 58 59] to explain upcoming or future performance outcomes. Conversely, gains in lean mass indices (range 3.1%–7.4%) favourably influenced endurance sport performance metrics (eg, increasing peak and/or average power output in cycling, sprint performance or work economy),[57 60–64] and jump skills and performance skills in racquet sports.[65] Interventions to reduce BM in athletes competing in combat/weight-making sports were more successful in maintaining health and performance outcomes when rates of loss were slow (<0.8 kg/week), weight loss period was extended (>4 weeks), total BM lost was limited (<3%) and the athlete was under the guidance of professional support.[66–68] In contrast, a short period for weight loss and/or a more aggressive weight loss rate resulted in impaired health and performance.[66 69] Furthermore, lean athletes (eg, <10% body fat) were more likely to experience adverse health, mood and performance outcomes (eg, loss of lean BM and related power/strength performance and impaired mental and cognitive performance).[66 68 70] From the longitudinal studies assessing talent identification or successful sport performance development, BC and BM were of relatively minor importance compared with variables including agility and technical skills.[59 71 72]

Survey on BC practices

The survey was completed online by 125 practitioners working within competitive sport in 26 countries, with primarily tier 3–5 athletes. The rationale for measuring BC in athletes (n=43 responses) was categorised into four themes: part of the routine measurement of performance-related variables (44%, n=19); to monitor the outcome of specific BC manipulations (33%, n=14); for health monitoring (23%, n=10) and to monitor growth and development (12%, n=5).

The communication of BC data (n=35 responses) was categorised in the following ways: the athlete is first in the communication flow (69%, n=24); the athlete decides on the flow of information (31%, n=11) or the communication is first directed to the dietitian/nutritionist/doctor (20%, n=7) or the head of performance (6%, n=2).

Changes over the decade

A comparison of key data collected from both the 2013 and 2022 surveys is presented in online supplemental table 2. The results from 2013 regarding method use are in contrast to 2022 with a +23% difference use of surface anthropometry (ISAK method), +11% for DXA and −40% in the proportion of those using skinfolds to estimate body fat (%). Meanwhile, less than 10% of respondents used ultrasound, hydrostatic weighing, air displacement plethysmograph or the calculation of body fat (%) from skinfold measurement in 2022. In both 2013 and 2022, 29% of respondents reported using BIA. The proportion of some standardisation strategies differed, including the use of recognised protocols (+34%), engagement of trained/qualified technicians (+10%), standardisation of pretesting conditions (+11%) and quantification of technician reliability (−17%) (online supplemental table 2). However, some elements of standardisation have remained similar particularly equipment calibration/consistency (−2%) and using the same measurer (−7%). Over the last 10 years, sports dietitians/nutritionists have become the most reported practitioners responsible for measuring BC, with a reduced frequency of BC assessment. In 2022, presenting absolute body fat (30%) or body fat (%) values (46%) differed to 2013 (55%; 68%), while information on fat free mass became more commonly reported (34%–49% in 2013; 57% in 2022). The primary sources of BC assessment request in 2022 were sports dietitian/nutritionist (74%), the athlete themselves (68%), coach (57%) and athletic trainer/physiotherapist (45%). This demonstrates a shift from 2013 when the coach was the most common initiator of BC assessment. The majority of respondents (78%) identified concerns associated with a focus on BC in 2022, and the proportion of response was similar to data from 2013 (69%) ($X^2=0.748$; $p=0.387$), demonstrating no change over the 10-year period. Themes that were identified in the 2013 survey were also consistently mentioned in the 2022 survey (online supplemental table 2) with three issues highlighted by >50% of 2022 respondents. There was a difference (+31%) in the proportion of comments relating to lack of knowledge and the perception that changes in BM/BC always improves performance and an increase (+10%) in those who thought there was a lack of guidance in goal setting. Conversely, the proportion of respondents that mentioned DE/EDs, female athlete triad, body image issues and injuries as an issue differed by −19% and −15% for those citing BM loss through pathogenic methods and dehydration.

DISCUSSION

This paper explores issues of BC considerations in sport by: (1) systematically reviewing the literature related to effects of BC on the performance of athletes; (2) reviewing the evolution of BC considerations in sport over the last 10 years and (3) providing best practice recommendations for BC considerations. Research exploring the association between BC and sports performance is limited and primarily focused on endurance athletes. While endurance sports performance may be impacted by BC, both fat mass and lean mass may be important to consider, still an optimal BC is difficult to define. Furthermore, the individual athlete response to BC manipulations is likely dependent on presenting physique traits, rate of change in BC or BM, the specific strategy applied and their personal psychological makeup. To avoid problematic LEA and REDs, these findings underline the need to consider the short-term and long-term health of the athlete rather than any arbitrary, defined sport-specific BC values. While the survey results point to many favourable changes in BC considerations, our findings highlight the need for guiding principle and protocol development for BC considerations in organised sport. This includes recommendations on who should be involved in the dialogue relating to BC considerations, and appropriate processes relating to BC assessment, when justified. This should alleviate the ethical concerns reported by practitioners in association with athlete well-being around BC considerations[23] and supports a need for best practice recommendations.

There is limited evidence from the available research that specific BC (eg, a given body fat percentage) is associated with competitive success. This review underscores the equal or higher importance of experience in sport (hours of exercise, age, exposure to competition),[52–54 56–59 71 72] noting that such persistence and specialisation result in the typical BC frequently seen in the specific sport. Hence, while elite athletes may have *more* muscle mass and *less* body fat than subelite athletes in some sports,[81–84] this may simply be a by-product of their persistent and periodised training.[84] Additionally, a range of other variables (eg, VO_{2max}, strength and/or power, peak power output, speed and agility) played important roles in predicting performance success,[57 71 72 78] giving BC a small to moderate effect per se.[53 54 56–58 76 78] This may be especially true for elite athletes as they approach morphological optimisation for their sport, which limits the ability for further change in physique. Interestingly, in highly trained endurance athletes (runners, skiers and cyclists), performance may benefit from the integration of strength training and accompanying site-specific muscle hypertrophy.[60 62–64] Still, while interventions focused on enhancing strength and muscle hypertrophy may be associated with favourable performance outcomes in some athletes,[61 67 85] these responses are not uniform across sport. Increased muscle mass and body mass may be problematic in some situations, including the effects on initiation of sprint acceleration and on achieving predefined weight categories.[66 86] Regarding reduction of BM, research indicates that athletes can reach performance optimisation without loss of muscle mass when BM reduction is achieved with professional supervision, and in a periodised and/or planned manner.[11 66 68] However, an intention to reduce BM via sustained energy restriction resulting in problematic LEA and REDs can also impair health[66 68 69] and as such long-term athlete performance.[87 88] Unfortunately, practitioners in our survey reported concern for athletes' health in response to the focus on BC. While acknowledging the potential favourable performance implications of periodically attaining lower body fat for a specific competition, especially in 'weight sensitive' or weight-class sports,[11] an overemphasis on achieving and maintaining low body fat may increase the risk for DE/EDs and REDs.[6 17 22] Such a biased approach also fails to acknowledge the important role played by lean mass,[59–61 63 64 78 80 85 89] even in weight sensitive and endurance sports. This confirms a need for a supervised and individual athlete approach, taking into consideration desired performance outcomes, individual athlete nuances (presenting BC and health status, including current eating behaviour, body acceptance and training) and access to relevant members of the athlete health and performance team. Thankfully, the survey results indicate a more holistic approach to reporting BC data over the past decade, including reporting both fat and lean mass, and a focus on longitudinal changes in individual athlete data. However, universal targets or safety limits for minimum body fat (%) within sport are still used and fail to consider individual athlete nuances and the differences in outcomes between BC assessment methods. Instead, best practice should aim for an evaluation of the individual athlete's BC

Table 1 Features of selected methods for assessing body composition in elite athletes

Method (approach)	Outcome measures	Assumptions/cautions	Accuracy	Precision/repeatability (technically)*	Advantages	Limitations
Anthropometry (skinfolds) (anatomical)	Skinfold thickness (compressed) Skinfold sum Skinfold ratios Conversion to BF (%) via equations not supported[92]	Several assumptions are required,[99] including: Constant skinfold compressibility Constant SAT compressibility Constant skin thickness Unknown proportion of embedded fibrous structures	Unknown	Intra-tester 5% TEM for ISAK-trained, skilled technicians[100]	Applicable in the field Standardised protocols Data norms available Non-invasive and no radiation Scores are minimally affected by exercise, hydration or ingestion of food Cost efficient	Measurer training necessary Samples of the subcutaneous fat deposit only Some sites difficult to achieve Measures primarily skin thickness in lean persons Can be intrusive for some individuals Some site locations not scaled to body dimensions
Ultrasound (anatomical)	SAT thicknesses (uncompressed) with fibrous structures included and excluded SAT mass SAT patterning	No image distortion with a linear probe Use the speed of sound in SAT for distance determination Use standardised protocol[101] Correct detection of tissue layer boundaries need training and experience Analysis must avoid some anatomical structures (blood vessels)	Accuracy 0.1 mm (18 MHz probe); 0.2 mm (10 MHz)	95% LOA=0.2 mm (for the mean of eight sites), which translates to 0.2 kg SAT mass[102]	Applicable in the field Standardised protocols Non-invasive and no radiation Scores are minimally affected by exercise, hydration or ingestion of food[103] High accuracy and precision of measurement of subcutaneous fat Scan site locations relative to stature No tissue compression Tissue thickness 0.1–100 mm	Measurer training necessary Samples the subcutaneous fat deposit only Expensive equipment
DXA (chemical)	Directly BMC Indirectly FM LBM	Interpolation for soft tissues in areas where bone is detected (40–45% of pixels affected)[92] Use standardised, best practice protocols [96] Awareness of misconceptions regarding which tissues comprise FM and LBM[98] Animal models used for human soft tissue calibration[98] Assumptions required and correction factors applied[104] when estimating soft tissue composition	Compared with multi-component models[105] %FM 2.0–3.0% SEE SM 1.6–4.4 kg SEE DXA calibration does not accommodate the physiques of lean athletes[101]	Scan-rescan analysis with repositioning[106] BMC 0.60% CV† FM 0.82% CV %FM 0.86% CV In 'athletic' populations[96] BMC 0.70% TEM FM 1.90% TEM LBM 0.40% TEM	Standardised protocols Data norms for BMD available Good precision for bone mineral Time efficient Small single scan radiation dose Whole-body approach Regional compartment analysis Provides estimate of whole body and regional FM, LBM and BMD	Not applicable to field work Inter-machine and inter-manufacturer variability Consideration of cumulative X-ray dose for multiple scans Cannot scan if pregnant Provides an indirect measure of LBM Calculation algorithms differ between manufacturers and are not published Pencil vs fan-beam outcomes differ Expensive equipment Restrictive exercise, fasting and hydration requirements prior to scanning (for athletes)

Continued

Table 1 Continued

Method (approach)	Outcome measures	Assumptions/cautions	Accuracy	Precision/repeatability (technically)*	Advantages	Limitations
Medical imaging MRI (anatomical)	Cross-sectional areas of Adipose Bone LBM Other tissues	MRI designed primarily for diagnostic use rather than quantifying tissue masses Calculation of tissue volumes and masses requires bespoke software Image segmentation (contour detection) requires subjective decisions Relating anatomical dimensions to tissue masses requires knowledge of tissue densities	Pixel size (~1.5×1.5 mm) limits accuracy for whole body scans, especially for lean persons[92] Consequently, MRI cannot detect accurately the fat layers below this pixel size	Unknown for body fat measurements	Non-invasive and no radiation Whole-body approach possible Regional compartment analysis possible Direct measure of skeletal muscle at site of assessment	Not applicable to field work Lack of published normative data Difficulties in discriminating accurately tissue layer boundaries Bespoke software necessary for quantification of tissue masses Long data capture for whole-body scans Confined space may induce claustrophobia Single or few slices are not representative of visceral or whole-body fat mass[107] Expensive equipment
Impedance (chemical)	Total body water (TBW) Body fat (BF) Fat-free mass (FFM)	Participant compliance to strict testing prerequisites assumed – including abstaining from exercise Assumes geometric similarity between individuals Assumes tissue resistivity is similar between individuals Input data (age, height, weight, athletic status) accounts for high (up to 85%) of variance in the outcome variable.	Compared with multi-component models for young adults[108] FFM—SEE 2.5–3.9 BF—SEE 3.6 TBW—SEE 1.7–3.8	Intra-individual CV 2.0–3.5%[108] Prediction errors 3.0–8.0% for TBW 3.5–6.0% for FFM	Minimal participant involvement Non-invasive and no radiation Rapid data acquisition Precision good for TBW Apparent sophistication	Accuracy poor – most have used questionable criterion measures for comparison Lack of standardised protocols Results affected by hydration and electrolyte status No athlete-specific equations Trunk contributes only a small proportion to total impedance Different electrode placement (arm–leg, leg–leg, arm–arm) Large variability for outcome measures between devices

*Does not necessarily consider biological variation.
†CV <5% denotes good precision; TEM <1.5% denotes acceptable reliability; 95% LOA denotes reliability is better than the given value in 95% of cases.
BF (%), percent body fat; BMC, bone mineral content; BMD, bone mineral density; CV, coefficient of variation; DXA, dual-energy X-ray absorptiometry; FM, fat mass; LBM, lean body mass; LOA, limit of agreement; SAT, subcutaneous adipose tissue; SEE, SE of the estimate; TEM, technical error of measurement.

Table 2 Best practice recommendations for BC considerations; recommendation for each point of the BC assessment/monitoring cycle

Stage of BC considerations process		Best practice recommendations*
1	Preparatory steps for consideration for BC assessment	▶ Athletes considered for BC assessment or manipulation are at Tier 3 level and above 18 years of age ▶ The athlete health and performance team should meet with the athlete, and if agreeable to the athlete, the coach. They should make an informed decision on the benefits and risks of BC assessment and/or manipulation. Non-negotiable risk factors that should determine that BC assessment should not be undertaken ▶ The athlete does not have appropriate access to an athlete health and performance team ▶ The athlete is <18 years of age and BC assessment is not indicated for medical purposes or other exceptional causes ▶ There are concerns around eating behaviours or physique/body image anxiety. BC assessment should be considered only for medical purposes ➔ *If there is no sound rationale for assessment or manipulation of BC:* ▶ No need for BC assessment, unless there is a significant change to training and/or health status (eg, injury) ▶ Reinforce nutrition; priority is to support fuelling and recovery, while maintaining health ➔ *If there is sound and supported rationale for assessment/manipulation of BC, without causing harm to athlete*: ▶ Assess the readiness of the athlete (eg, eating behaviour, history of EDs, body image and physique anxiety)[114]
2	Document written informed consent	▶ The process for BC assessment should be clearly outlined to athlete and scheduled with other relevant assessments ▶ Education should be delivered to athlete and their support team members on topics such as BC, nutrition, training, and the interactions among these areas ▶ The athlete should retain the choice of whether BC assessment is conducted, the decision should be rechecked regularly, even if medically indicated, and given the option to change their decision to participate without repercussions at any time ▶ Explicit consent for BC assessment should be documented prior to BC assessment
3	Method choice	▶ BC assessment should be completed by suitably trained/accredited individuals who have the required professional skills to navigate psychological sensitivities around BC ▶ The most appropriate method for BC assessment should be chosen based on technical (scientific evidence and technological progress, safety, validity, precision, and accuracy of assessment), practical issues (availability, financial implications, portability, invasiveness, time effectiveness, method consistency), and the availability of technical expertise to conduct procedures (see table 1) – Consideration should also be given whether the method of BC assessment can accommodate the unique BC characteristics of some athletes (eg, body size, extreme leanness), the impact of high daily fluxes in body water and muscle solutes on estimates of BC, and the sensitive nature of assessment (eg, measuring BM blinded)
4	Data collection	▶ The athlete should be educated on the procedures for the selected methods of BC assessment in advance. This should include the opportunity to ask questions ▶ A standardised protocol should be followed prior to and during BC assessment to optimise the reliability and validity of the data. Exact protocols will vary according to the method of choice and any deviations from the standardised protocol during any assessment should be duly recorded ▶ BC assessments should be scheduled to coincide with the capture of relevant health and performance metrics that will provide insight into the impact of dietary and training intervention on well-being and performance ▶ Athletes should be given the option of having a chaperone of their choice present during the assessment. The coach should not be present unless this is agreeable to the athlete and serves a valuable purpose ▶ Measurements should be conducted in a designated space with adequate privacy and controlled access. This includes data privacy ▶ The precision error of measurement specific to technician and BC assessment method should be known. This information should preferably be captured as a between-day estimate to account for both technical and biological error ▶ The collection of BC assessment data should be scheduled to allow protocols to be followed carefully and to allow the athlete to ask questions or discuss concerns ▶ BC data should be treated as confidential medical data and processed, handled and stored accordingly
5	Data interpretation	▶ Unless explicitly specified otherwise, results should not be made available to the athlete at time of data capture ▶ Sufficient time should be taken to ensure that data are interpreted accurately, and analysis is carefully conducted within the athlete health and performance team ▶ Interpretation of BC data by the athlete health and performance team should integrate method precision error plus other health and performance parameters. Such interpretation should be sport-specific and athlete-specific

Continued

Table 2 Continued

Stage of BC considerations process		Best practice recommendations*
6	Data reporting	▶ BC data should be presented in an accessible format that integrates precision error data alongside previous individual results (where available) ▶ Normative/reference values should not form part of the data report for individual athletes
7	Data dissemination and communication	▶ Athletes should have the right to grant or deny access to their BC data ▶ BC results should be shared directly with the athlete, with consideration of appropriate timing and language of choice used ▶ Where consent is provided, results should be discussed in a private setting with the athlete through appropriate member/s of the athlete health and performance team (ie, sport dietitian/nutritionist or sport scientist preferred) ▶ Discussion and agreement to further action (eg, intervention) should occur between the athlete and appropriate members of athlete health and performance team ▶ BC data are treated confidentially and stored with same security as electronic medical records as per local privacy laws
8	Monitoring	▶ An agreed timeline and frequency of BC monitoring should be determined to align with agreed intervention ▶ Relevant representatives from the athlete's health and performance team should support the athlete and coach to implement an intervention to optimise health and performance ▶ Follow-up assessments should be scheduled, taking into consideration the anticipated response, plus the precision error of test, and other relevant metrics ▶ The frequency of follow-up measurements should not normally exceed 4–6 times per year ▶ Athlete readiness should be re-assessed (see stage 1) prior to follow-up assessments to determine if assessments should continue ▶ Any new concerns relating to BC assessment should be discussed with the athlete's athlete health and performance team

*All steps to be included in an organisation' policy regarding BC assessment/considerations.
BC, body composition; BM, body mass.

in comparison to individual, previous BC data and in association with performance and health variables in interpreting the impact of BC change on performance. For most athletes, performance outcomes are far more dependent on specific training, technique and cognition, than a specific BC.[59 71 72 90 91]

Our survey on current practices relating to BC identified subtle changes since the 2013 survey. We report a reduction in the frequency of assessment, less frequent use of the calculation of body fat (%) from skinfold measurements (−40%), a seemingly greater awareness of best practice protocols and a focus on dietitians/nutritionists (+24%) and sport scientists/physiologists (−1%) for data capture. Whether these changes are because of actual improved management, or a result of recruiting different respondents to the surveys, is difficult to ascertain. Nevertheless, the current survey respondents, with the majority working with tier 4–5 athletes, reported concerns related to the focus on BC both by athletes and coaches, potentially leading to increased risk for body dissatisfaction, DE/EDs and problematic LEA and REDs. Over the last 10 years, problems associated with this focus on BC remained a consistent concern for practitioners (2013: —69%, 2022: —78%). All of the problems reported in 2013 regarding BC assessments were also reported in 2022, highlighting a lack of sufficient progress in the field. Other recurring problems included a lack of knowledge; perceptions that changes in BM/BC always improve performance and lack of guidance in goal setting for BM/BC within sport. In summary, practitioners identified a continued need for increased awareness of how performance and health are affected by BC assessment, manipulation and overall considerations, and better guidelines for approaching, conducting and disseminating information on BC assessment.

Available methods for BC measurements

An array of techniques is available for the assessment of BC, each with their own assumptions, advantages and limitations. There is no single, universally accepted gold-standard measure of BC[92] and it is challenging to compare results derived from different techniques.[48 92–94] It is important that any technique is undertaken in accordance with a standardised protocol that maximises the best features of the technique and optimises opportunities for longitudinal monitoring.[48 79 92 95–97] To help practitioners understand the importance of optimal technology for BC assessment, specifically when working with elite athletes, we include an overview of BC methods that are practical for field and/or laboratory use (table 1). While ultrasound seems to be rarely used (*see survey results*), lacks published reference values and has limitation in providing a whole-body analysis; the accuracy of skinfolds remains undetermined. Furthermore, DXA soft tissue estimates require data interpolation when bone is encountered within the scan (40%–45% of pixels), which may cause large errors, especially for lean persons [23]. Still, an advantage with DXA is the additional information on bone mass. As such, though more costly and with some interpretation cautions,[96 98] DXA is a recommendable method when conducted according to best practice,[96] and when interpreted in light of the limitations identified (eg, an indirect measure of muscle mass, calculation algorithms are unpublished and differ between manufacturers and the intermachine and intermanufacturer variability).

BC considerations: a whole system approach

Overemphasis on BM and BC and lack of informed consideration given to the performance and health implications of manipulating BM and/or BC has the potential to result in adverse outcomes. Indeed, poor administration of BC considerations and assessment procedures may predispose an athlete to adverse health and performance outcomes in response to inappropriate dietary adjustments. There is also a strong argument for avoiding BC assessment and manipulation in athletes younger than 18 years, other than when medically indicated for growth and development monitoring.[23] Exceptional circumstances may exist where BC assessment may be justified for athletes <18 years. Still, such decision warrants careful consideration and

Figure 1 A paradigm shift for best practice recommendations for body composition assessment and wider consideration. A visual presentation of the BC assessment and considerations process involving the athlete health and performance team. The model and guidelines represent best practice recommendations to reduce the risk DE/EDs, problematic LEA and REDs because of an overly BC focus and associated considerations. Practice examples are based on survey results and practitioner experience. BC, body composition; DE, disordered eating; ED, eating disorder; LEA, low energy availability; other parameters, relevant health and performance information; REDs, Relative Energy Deficiency in Sport; other parameters, relevant health and performance test results or information.

consensus among the athletes' health and performance team and require guardian consent. *Indeed, adolescent athletes should focus their attention on purposeful training to further develop physical and skilled performance, complemented by a nutrition strategy that facilitates a positive relationship with food and body, supports growth and prioritises optimal fuelling for and recovery from training.*[109] Considerations for the negative health impacts of frequent weight cycling during a sporting career or postsport life are also typically ignored.[110–112] The manipulation and associated assessment of BC should be underpinned by a purposeful and considered process involving key members of an athlete's health and performance team rather than the result of a coach's and/or athlete's uninformed preferences or desire for monitoring. The athlete health and performance team must be multidisciplinary, including a qualified, experienced sports dietitian/nutritionist, sports physiologist/strength coach, psychologist and sports medicine physician as a minimum. Results from the survey highlight the potential issues triggered by poor practice relating to BC considerations and that these problems continue to exist 10 years on from the first survey. With a view to minimising the risks and enhancing the benefits of the BC assessment and associated considerations, table 2 and figure 1 illustrate best practice protocols that should be followed before and at each stage of an assessment process. The recommendations result from a comprehensive evaluation of the survey, the literature review and the practical experience and scientific merit of the multidisciplinary group of authors. Overall, a standardised process needs to be transparently captured in the guiding principles and protocols of a sporting organisation. Effective communication is an overarching principle of the process and particular care should be taken to ensure that there is adequate opportunity for this to occur.

How to minimise risk for REDs caused by DE and an overfocus on BC

While athlete education and improved access to accredited health professionals may reduce the risk of exposure to unintended LEA,[36 41 43] the link between LEA, body dissatisfaction and the high risk and frequency of DE and EDs in sport requires further attention.[6 113] Indeed, the need for interventions to address issues identified by practitioners in this investigation was evident 10 years ago.[48] While stakeholders speak of the importance of *information* to prevent unhealthy dieting and idealisation of physique,[6 23 114] the effect of such dialectic methods on individuals with symptoms of ED psychopathology is less robust.[115–117] Promising findings come from interventions aimed at reducing body dissatisfaction and preventing EDs among adolescent athletes.[118–122] Here, participating in interactive workshops, which involves either discussions or cognitive dissonance tasks, has been shown to decrease risk factors for EDs and reduce the onset of new EDs in young elite female athletes during 1 year of follow-up.[120] Programmes aiming to prevent body dissatisfaction and EDs must achieve changes in attitudes and behaviour and increase knowledge (prevention, level 1). Importantly, specific measures must target how sport is arranged, hence, aim to reach higher levels within organisation of sport, like the club, national and international administrations. This includes specific local culture within a sport (prevention, level 2),[14 15 123] incorporating coaches' knowledge on BC and biological development, general communication style and the specific language used to discuss BC.[42 121 124 125] Furthermore, national and international sport federations need assistance to address characteristics of their sport, including competition regulations, which perpetuate unhealthy practices around BC considerations (prevention, level 3).[6 114] Here, rule changes have been implemented in several sports, including ski jumping and figure skating,[6] and more recently in beach handball, gymnastics, artistic swimming and sport climbing, to reduce the risk of developing REDs associated with participating in such sports.

Limitations

Multiple research studies have examined the correlation between BC and sport performance at single points in time. By design, these studies were not included in this critical review. Instead, we focused on research that examined the impact of BC change on sport performance over time. This limited the search to a small number of investigations, primarily on endurance or long-distance sports. Little is known about the impact of BC change on performance outcomes in other sports, especially among elite athletes. Furthermore, few studies provided sufficient detail in their methodology to critique compliance with best practice protocols. Failure to comply with such guidance is known to significantly impact estimates of longitudinal change in BC.[94] Nevertheless, we emphasise the principle that ideal BC is specific to the individual athlete and sport.[6] Methodological limitations of the review are the use of only one database and having only one author to screen literature, hence increasing the risk of missing relevant literature. Additionally, due to the limited and heterogeneous studies identified, no meta-analysis was possible. A variable and occasionally low number of responses to each of the questions within the survey also limit the generalisation of findings. Statistical analyses were performed for comparison between the 2013 and 2022 surveys, but this was not possible for all questions, which limits the statistical differences that can be identified between the surveys. While the survey on BC considerations was conducted by practitioners, there is a need to explore athletes' perceptions and experiences of BC assessment and broader BC consideration issues. Although preliminary research confirms that issues exist,[126] broader exploration of such experiences is needed. Additionally, we need to increase our understanding on coaches' knowledge of REDs and how organisations deal with BC-/REDs issues, and the aetiology of REDs and why individual athletes may be affected or spared. As such, there is need for controlled interventions aiming to prevent risk factors for REDs among athletes and coaches and evaluation of real-life implementations of best practice protocols of BC assessment to explore the mental and physical effects in athletes of different sports, including early indices of problematic LEA and REDs.

PRACTICE IMPLICATIONS

While significant progress has been made in the methods of data capture and frequency of BC assessment, the 2022 survey brings continued concerns relating to BC practices in sport. A paradigm shift from current practice is required to enforce awareness, correct misperceptions and to ensure that BC considerations are not an antecedent of REDs. Thus, we present a best practice recommendation to support such a change. Figure 1 points to this paradigm shift and illustrates how this can be achieved at different stages of the BC considerations process, by highlighting best practice recommendations (ie, safety measures, evaluations and professional involvement). There are often barriers to the application of best practice, and these must be addressed to move forward with BC considerations. As supported by the survey, barriers to implementation include, but are not limited to, resources (time, appropriate staffing, equipment, knowledge) and perceptions and influence of others. A system that facilitates best practice is one that invests time and resources to support staff, which requests certification and recertification and education in appropriate BC assessment (including potential negative consequences and risk, communication of results and management of any proposed subsequent intervention). There are inherent ongoing challenges associated with BC considerations that must be carefully navigated. The individualised nature of BC considerations and its association with performance and health, and individual responses to interventions and changes in BC, take time to establish. Because it is impossible to set universally valid reference values for BC, the complexity of BC considerations for health and performance increases. Finally, the perceptions and beliefs of coaches, athletes, medical and support staff regarding BC and performance make major shifts in practice a challenge, but this must be addressed to harness the potential benefits of BC manipulation when justified with low or no risk. We believe that the proposed best practice guidelines in this paper (table 2, figure 1), including the appropriate choice of BC assessment method where justified (table 1), may shift the risk of harmful health effects to goal-oriented performance and health enhancement.

CONCLUSION

This critical review on the relationship between BC and sport performance found limited evidence for the benefit of any specific BC, but highlights an advantage of leanness in endurance sport, muscle mass across most sports and persistent training and experience for talent development. Concurrently, although our survey on BC considerations points to some favourable changes in practices over the past decade, issues remain, like poor standardisation of methods, comparisons to some arbitrary sport-specific ideal BC and concern for the well-being of the athletes. Building on the current findings and practical experience, the authors suggest in this paper a detailed recommendation for BC considerations. When deemed appropriate to undertake BC assessment or manipulation, individual athlete support should be provided to mitigate health risks. This risk mitigation should include prescreening by a multidisciplinary athlete health and performance team. The assessment technique should be chosen wisely and implemented using appropriate standardisation of routine for the equipment and assessment protocol. Assessments exceeding 4–6 times per year are likely unnecessary, and assessment of athletes younger than 18 years of age is not recommended. Because assessment or manipulation of BC may pose a risk to athlete health and performance, due consideration should be given to such initiatives before implementation.

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