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## “I’d got self-destruction down to a fine art”: a qualitative exploration of relative energy deficiency in sport (RED-S) in endurance athletes

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### ABSTRACT

Relative Energy Deficiency in Sport (RED-S) is a syndrome of impaired health and performance that occurs as a result of low energy availability (LEA). Whilst many health effects associated with RED-S have been widely studied from a physiological perspective, further research exploring the psychological antecedents and consequences of the syndrome is required. Therefore, the aim of this study was to qualitatively explore athlete experiences of RED-S. Twelve endurance athletes (female  $n = 10$ , male  $n = 2$ ;  $M$  age = 28.33 years) reporting past or current experiences of RED-S, associated with periods of LEA, took part in semi-structured interviews designed to explore: contexts and mechanisms underpinning the onset of RED-S; the subjective experience of RED-S; and contexts and mechanisms influencing “recovery” from RED-S. Regardless of how RED-S was initiated, all athletes experienced a multitude of physiological impairments, accompanied by significant psychological distress. This paper contributes novel understanding of the complex interplay between physiological and psychological components of RED-S from the perspective of information-rich cases. The findings suggest that system-wide educational prevention and awareness interventions are vital for athletes and support personnel, such as coaches, parents, dietitians, psychologists, and sports medicine staff.

### ARTICLE HISTORY

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### KEYWORDS

Low energy availability; female athlete triad; disordered eating; eating disorders; compulsive exercise; endurance

### Introduction

The protection and maintenance of athlete health have become an area of increased priority for sporting organizations in recent years (Mountjoy & Junge, 2013). A topic of particular focus concerns the deleterious implications of low energy availability (LEA) on psychological and physiological wellbeing. Low energy availability occurs when an individual’s energy intake is insufficient to support optimal physiological functioning, after exercise energy expenditure (expressed in relation to fat-free mass) has been taken into account (Loucks et al., 2011). Relative Energy Deficiency in Sport (RED-S) refers to a syndrome of impaired physiological functioning that occurs as a result of LEA, with two conceptual models depicting the range of proposed health and performance effects that characterize RED-S (Mountjoy et al., 2014). Whilst substantial evidence has been generated to support some components, especially those historically associated with the Female Athlete Triad (Triad; see Nattiv et al., 2007), further evidence is required to advance knowledge of other proposed effects, including interactions with psychological health, which have been scarcely investigated (Schofield et al., 2020). The potential adverse psychological effects of combining high levels of PA with inadequate nutrition are wide-ranging and include: anxiety; depression; substance misuse; disordered eating (DE) and eating disorders (ED; Mikkelsen et al., 2017; Rice et al., 2016). It is important to note, however, that psychological health impairments may also initiate a state of LEA (Mountjoy et al., 2014), making it difficult

to establish whether psychological factors precede or succeed the physiological complications. For example, physiological consequences of DE/ED mirror many of the health and performance implications associated with RED-S. It is, therefore, crucial to advance understanding of the psychology of RED-S to mitigate or treat any such outcomes.

Due to the substantial energy demands associated with sustained physical activity, athletes are more susceptible to experiencing LEA, and therefore RED-S, than less physically active individuals (Logue et al., 2018). Whilst a “gold standard” method for measuring LEA has yet to be established, prevalence estimates range from 6% (Hoch et al., 2009) to 100% (Doyle-Lucas et al., 2010) across various athletic pursuits (Logue et al., 2020). In turn, this suggests that a large proportion of exercising populations could be at risk of experiencing psychological symptoms associated with RED-S. Moreover, sporting contexts requiring or emphasizing the importance of low body fat and a lean physique (e.g., weight-sensitive and endurance sports) can encourage dietary energy restriction and/or increased exercise energy expenditure due to beliefs that this could confer a performance and/or aesthetic advantage (Robertson & Mountjoy, 2018). Endurance athletes are considered particularly vulnerable to developing RED-S as they face sociocultural pressures of a sporting body “ideal” (Thorpe & Clark, 2020), and tend to have significantly higher energy requirements than individuals participating in other physical pursuits (Loucks, 2007).

In contrast to other RED-S symptoms, Mountjoy et al. (2014) proposed that “psychological consequences can either precede

or be the result of RED-S" (p. 493), as illustrated by a bidirectional arrow in the RED-S health consequences model. The evidence base to support this notion, however, remains limited, with much unknown about the psychological antecedents underpinning the occurrence of RED-S (Mountjoy et al., 2018). Indeed, the distinction between risk factors and consequences of LEA has become difficult to extricate, due to inconsistencies in the terminology used to describe it, and methods employed to estimate its prevalence (Bratland-Sanda & Sundgot-Borgen, 2013). For example, a small number of studies indicated that female adolescents with functional hypothalamic amenorrhoea (FHA) exhibit depressive traits (Marcus et al., 2001), a reduced ability to cope with stress, and need for social approval (e.g., Strock et al., 2020). However, these factors have been commonly observed among athletes with DE/ED (e.g., Shanmugam et al., 2014), thus making it difficult to identify whether they are inherent to pre-existing eating psychopathology or FHA (i.e., that occurs as a result of LEA; Loucks, 2007).

To date, eating psychopathology remains the most extensively researched psychological health concern associated with LEA, and has been found to be twice as prevalent in athletes than sedentary populations (Martinsen & Sundgot-Borgen, 2013). Pressures to achieve and maintain a lean physique, present in many sports, can promote restrictive eating practices (reducing energy intake), which may progress into DE behaviour, or more severe clinical ED (Krentz & Warschburger, 2011). It has been proposed, however, that intentional reductions in EA can reflect "rational but mismanaged efforts to reduce body size and fatness" (Loucks et al., 2011, p. S8), suggesting such practices may occur in the absence of DE/ED. Furthermore, some athletes experience inadvertent LEA, whereby reductions in energy intake and/or increases in exercise energy expenditure are not intentional, but are attributable to prolonged, high-volume exercise or insufficient nutritional knowledge (Loucks, 2004). As such, this emphasizes a need to understand not only the psychological mechanisms underlying the occurrence of RED-S, but additional practical barriers to achieving optimal energy availability.

Another important area that warrants further attention is how individuals recover from RED-S. Subjective appraisals of recovery from LEA and RED-S have received limited attention within the sport science and medicine literature, which has predominantly relied on objective biomedical thresholds (e.g., weight restoration, resumption of regular menses in females) and absence of diagnostic criteria for clinical ED (e.g., low body mass index). Whilst a small number of qualitative studies have explored athlete experiences of ED recovery (Arthur-Cameselle & Quatromoni, 2014; Papathomas & Lavalley, 2010), these findings cannot be generalized to inadvertent cases of RED-S in which ED may not be present. Although a RED-S clinical assessment tool (RED-S CAT) was developed to aid management of RED-S and return to play decisions in at-risk athletes (Mountjoy et al., 2015), it only briefly acknowledges the importance of

psychological factors (e.g., engaging with sports psychologists). Furthermore, it offers little insight into how recovery is conceptualized from the perspective of individuals who have experienced RED-S, thus indicating that further research is required to understand the psychological "recovery journey" from RED-S.

The aim of this study was to qualitatively explore the subjective experience of RED-S in endurance athletes. In addressing recent calls for further qualitative inquiry into individual experiences of RED-S (Schofield et al., 2020), this study employed qualitative interviews with information-rich cases (Patton, 2014) to explore the RED-S experience and the contexts and mechanisms underpinning its occurrence. In turn, the findings could provide novel insights into how RED-S can be prevented and managed, which would help to improve education, awareness, and treatment of RED-S (Statuta et al., 2017). Consequently, this could better equip athletes to achieve and maintain optimal EA, which is desirable not only for performance, but for longer-term health and wellbeing.

## Methods

### Philosophical orientation

This study was informed by a critical realist ontological position, which postulates that the nature of reality is not reducible to knowledge of reality (Fletcher, 2017). Critical realism emphasizes the importance of seeking causal explanations for social phenomena and seeks to generate insights into *how* and *why* specific phenomena occur (Maxwell, 2004). A critical realist ontology lends itself to the in-depth study of a relatively small sample of individuals and to textual forms of data that retain the chronological and contextual connections between events (Maxwell, 2012). As such, a qualitative approach was considered the most suitable methodology for this exploratory research and has been previously employed in cognate areas, including ED (Plateau et al., 2014) and addiction research (De Grace et al., 2017).

### Participants

Twelve endurance athletes (female  $n=10$ , male  $n=2$ ;  $M$  age = 28.33 years,  $SD = 6.20$ ) from England ( $n=11$ ) and Northern Ireland ( $n=1$ ) took part (Table 1). The primary sports of the athletes were endurance running<sup>1</sup> ( $n=9$ ) and ultra-endurance running<sup>2</sup> ( $n=3$ ), however all participants were involved in multiple physical pursuits at the time of recruitment (Table 1). While the study inclusion criteria sought participants across all sports (see Procedures), the gender and athletic background of the sample reflects past literature highlighting a gender disparity and predominance of endurance athletes in LEA research (Logue et al., 2018). All participants are hereafter referred to by numbers.

<sup>1</sup>Endurance running was defined as "running distances and competing in events of 5 km or longer" (Lieberman & Bramble, 2007, p. 288) but less than 42.2 km (based upon below definition of ultra-endurance running)

<sup>2</sup>Ultra-endurance running was defined as "events that involve running more than 42.2 km/26.2mi" (Roebuck et al., 2018, p. 43).

**Table 1.** Participant demographics.

Participant (number)	Sex	Age	Participation level <sup>1</sup>	Primary sport	Additional sport/exercise during RED-S experience
1	M	23	Semi-elite	Endurance running	Football
2	F	30	Sub-elite	Ultra-endurance running	Triathlon, pointe ballet, strength training
3	F	27	Sub-elite	Endurance running	Track-and-field athletics
4	F	40	Sub-elite	Endurance running	Strength training, fitness training (gym)
5	F	39	Sub-elite	Ultra-endurance running	Cycling, triathlon, football
6	F	26	Sub-elite	Endurance running	Triathlon
7	F	28	Semi-elite	Endurance running	Swimming
8	F	32	Sub-elite	Endurance running	Hiking
9	F	39	Sub-elite	Ultra-endurance running	Cycling, strength training
10	F	26	Sub-elite	Endurance running	Swimming, netball
11	F	24	Sub-elite	Endurance running	Fitness training (gym), swimming
12	M	36	Sub-elite	Endurance running	Rugby, strength training

Notes: Participants categorized based on criteria advanced by Swann et al. (2015). RED-S = relative energy deficiency in sport.

## Procedures

Ethical approval was granted by an ethics committee at an English university. Using purposeful sampling, we sought to recruit information-rich cases (Patton, 2014) to acquire detailed insights into individual experiences of RED-S. An electronic study information poster was circulated via emails to gatekeepers (e.g., coaches) and on social media (e.g., Twitter) and a printed paper version of the poster was handed out at an educational workshop for endurance athletes to individuals expressing interest in participation. Participants were required to: be 18–40 years of age; self-identify as having a past or ongoing experience of RED-S; and be participating in sport or exercise for at least 150 minutes per week during the time of self-identified RED-S. The recruitment materials did not refer to DE/ED diagnostic criteria to circumvent the potential omission of individuals with sub-clinical eating psychopathology or inadvertent experiences of RED-S. Self-identified onset of RED-S reflected a period during which participants became aware of health or performance effects of LEA (e.g., injury, illness) following increases in exercise energy expenditure and/or reductions in energy intake. Each prospective participant who had contacted the first author to express interest in taking part was subsequently sent an information sheet via email detailing the study aims. All athletes provided informed consent to participate and permit audio recording of their interview. Seven interviews were conducted face-to-face, while the remaining five interviews took place via Skype™. A consistent approach was employed to minimize differences between interview methods and provide a safe and comfortable environment in which participants could share their experiences. To establish rapport, the first author revisited the study aims and explained the interview format to each participant. Furthermore, to reduce the likelihood of “unanticipated harm” (DiCicco-Bloom & Crabtree, 2006), all participants were: reminded of the potentially sensitive nature of the topic; encouraged to voice any concerns if they arose; and reminded of their right to take a break from the interview or withdraw at any time.

## Interview schedule

A semi-structured, open-ended interview approach was adopted to allow the participants to elaborate freely and at length about their experiences (Smith & Sparkes, 2016). The interview schedule explored athletes’ experiences of RED-S,

from onset to present day, and questions cohered around: demographic information; chronological recall of the onset of RED-S (e.g., “can you remember when you first experienced RED-S?”); exploration of the RED-S experience (e.g., “can you recall any behaviours during this time?”); and the participants’ current psychological and physiological status (e.g., “can you describe how that time compares to now?”). In addition to these themes, specific probing questions (e.g., “can you tell me more about that?”) were employed to encourage more detailed insights into areas of interest. Prior to concluding the interview, the first author asked participants to discuss any additional areas that were not addressed. All interviews ( $M$  length = 54 minutes,  $SD$  = 13.72; range = 27–71 minutes) were conducted by the first author and transcribed verbatim within three days of taking place, in preparation for data analysis. This enabled the researchers to identify a discernible reduction in new codes emerging from the dataset, following the twelfth interview, at which point it was deemed that data saturation had been reached.

## Data analysis

An abductive approach to data analysis was employed (Timmermans & Tavory, 2012) to investigate the extent to which the data supported existing theory (i.e., deduction), whilst also providing the flexibility to generate new understandings or explanations (i.e., induction; Kennedy & Thornberg, 2012). Thus, such an approach enabled qualitative exploration of the RED-S paradigm, in addition to its antecedents and consequences. Data were analysed using a team approach in accordance with the six steps of thematic analysis (TA; Braun & Clarke, 2006). Initially, the first author familiarized herself with the data through the process of indwelling (Maykut & Morehouse, 1994): listening to the audio-recordings following each transcription to ensure accuracy, before reading each transcript at least twice. After gaining a sense of each athlete’s experience, transcripts were searched for relevant quotes pertaining to RED-S onset, experience, and efforts to overcome its effects, to generate initial *codes*. Similar codes were grouped together into *sub-themes* and this strategy was repeated to develop more substantive *themes* and subsequent overarching *categories*, prior to producing a final report (see Results). Throughout the analysis process, the other authors were provided with preliminary insights and asked to critically evaluate the first author’s interpretations (see below).

### Trustworthiness

The term *trustworthiness* is used to describe methods employed to strengthen the quality of qualitative research (Smith & McGannon, 2018). Several methods were adopted to enhance trustworthiness. To encourage reflexivity, written and digital reflective notes were compiled in a personal journal by the first author (see Braun & Clarke, 2019). The fifth author adopted the role of a *critical friend* throughout analytic procedures by reading and interpreting transcripts and appraising the first author's analysis. In turn, these critical discussions encouraged the first author to re-examine her interpretations of the data, which facilitated further reflexivity (Braun & Clarke, 2019). Furthermore, the research team engaged in formal *peer debriefing* (Creswell & Miller, 2000) meetings throughout data analysis, which helped to further challenge the first author's interpretations.

### Results

Consistent with the chronological format of the interview schedule, and sequential nature of participants' recalled experiences, the findings are presented in the following sections: the onset of RED-S; the subjective experience of RED-S; and efforts to overcome RED-S. Within each section, themes generated through the analysis are described and emboldened, with sub-themes italicized in text. Illustrative quotes are used throughout to amplify the voice of participants.

#### The onset of relative energy deficiency in sport

Participant accounts of the onset of RED-S cohered around interactions between personal and situational factors, which created the "perfect storm" for triggering intentional or involuntary changes to eating and exercise behaviours. The findings are presented in two categories: onset contexts, and onset mechanisms (Table 2).

#### Onset contexts

Three contexts appeared to shape athletes' thoughts, feelings, and behaviours towards fuelling and training and ultimately resulted in RED-S: **sport-specific pressures; social environment; and psychological health**. Both the *sporting culture* and *physical demands* of frequent endurance activity were reported to have negative influences on dietary intake and overall EA. Participant 9 described how cultural pressures inherent to ultra-endurance running encouraged her restrictive eating habits: "I think in some ways being a runner made that [guilt] worse ... you are hungry and you do need to fuel but you've been socialized to feel guilty for it". Significant life events, including *trauma, loss, and grief* preceded restrictive eating or excessive exercise habits for many: "Running was my way of getting over the [relationship] break up ... it felt like my way of escaping things" (Participant 6). Other athletes disclosed *pre-existing ED and DE behaviours* prior to their competitive sporting involvement: "I've had issues around food before I got into running ... running has just basically been a way of me controlling it [weight]" (Participant 4). Finally,

a need for *social approval* appeared to increase body dissatisfaction and peer comparison: "Someone told me my bum was too big, and the thought that there was anything wrong with me that people didn't like, I had to fix it" (Participant 8). Overall, these contexts were reported as precursors to the development of RED-S.

#### Onset mechanisms

The mechanisms by which RED-S was initiated were captured by two themes: **physiological mechanisms** and **psychological mechanisms**. Psychological mechanisms included a *perceived need for control*, often activated by significant life events. When linked with high-achieving traits, perfectionist tendencies (*trait expression*), and *low self-worth/confidence*, this would manifest into a need to train harder, eat "better", and achieve more: "I was probably running about 60 miles a week, but was like 'you're not doing enough, you've got to do more' so it turned into 70, then 80, and then things started to break" (Participant 9). Another notable finding concerned the prevalence of inadvertent cases of RED-S. Half of the athletes reported unintentional increases in exercise energy expenditure (e.g., *increased training loads*) that were insufficiently matched by energy intake, often attributed to a lack of awareness of their increased nutritional requirements. However, subsequent changes to body composition and short-term performance improvements appeared to encourage a heightened awareness of diet, exercise, and body image, prompting *restrictive eating practices*:

I increased my expenditure but not intake ... then you get faster because you're training more and getting slightly lighter and your brain goes "surely you can eat even less, weigh less, and get even faster." (Participant 10)

#### The subjective experience of relative energy deficiency in sport

The various features of the experience of RED-S (Table 3) were represented by three themes: a body thrown into disarray; a psychological warzone; and a vicious cycle of disordered eating and compulsive exercise.

#### "Broken": a body thrown into disarray

Following inadvertent or intentional reductions in energy intake, often accompanied by simultaneous increases in exercise or sport-specific training load (exercise energy expenditure), the physical health consequences of RED-S became apparent to participants. *Substantial weight loss* and *reductions in body fat* were appraised as desirable outcomes, or necessary conditions for performance gains:

I had a body fat percentage of 12% and everybody was like 'that's amazing you've got the perfect physiology you're obviously doing something right' ... nobody said to me 'that's not really a healthy body fat percentage to sustain for a long time' (Participant 9)

Such improvements, however, were short-lived, due to significant physical injury (e.g., stress fractures) or illness (e.g., virus). All females had incurred at least one *bony stress injury* and

**Table 2.** Contexts and mechanisms influencing the onset of RED-S.

Example raw data codes	Sub-theme	Theme	Category
It was really really drilled into us basically that you know if you were still getting your periods you probably weren't training hard enough	Sporting culture	Sport-specific pressures	Onset contexts
My running training was probably absolutely fine but my problem was what I was doing in addition... so my training schedule might have been say ten hours of running over a week but you could probably double that with everything else that I was discounting	Physical demands of sport and exercise		
I can really remember someone saying to me that they wanted my legs or something. And cause it had like come at a point where I'd just been like changing my diet and doing a bit more exercise, I thought "oh I can't stop now"	Social approval	Social environment	
I lost grandparents in a short space of time and although fuel-wise and all the signs in my body were pretty good I think I just started training a bit too hard to just cope	Trauma, loss and grief	Psychological health	Onset mechanisms
Because I had an eating disorder before I started running, I wasn't eating enough anyway, for just kind of like, working my body normally. just going to work and not doing any exercise	Pre-existing DE/ED		
I like started trying to control what I ate and then it became a control thing like I couldn't ever have that one chocolate bar or that one chocolate because then I might have it everyday	Perceived need for control	Psychological mechanisms	
The way I sort of dealt with my problems was very much, just kind of an all or nothing implosion. It's like 'that's the bottom line, you're not good enough, what's the matter with you, just train harder	Low self-worth or confidence		
And I suppose like I've always been a pretty driven perfectionist kind of person and just, and a people pleaser too so the thought that there was anything wrong with me that people didn't like, then I had to fix that	Trait expression		
I just sort of you know again quite unscientifically just ran more and didn't stop. Eat sleep and breathe training basically in some form	Increased training load/PA	Physiological mechanisms	
I think I'd read things, people talking about clean eating and things they don't eat... so I just kind of didn't eat puddings and sweet things, cutting them out entirely was probably quite a big change for my body	Restrictive eating practices		

DE = disordered eating; ED = eating disorder; PA = physical activity

menstrual dysfunction during self-identified RED-S, as well as a history of menstrual irregularities or amenorrhoea (e.g., late menarche, oligomenorrhoea). Others described overall feelings of *fatigue, weakness, and reduced energy*, in addition to: *thermoregulatory, haematological; endocrine; gastrointestinal; and immunological health* complaints (Table 3). Participant 6 reflected on impairments she believed were necessary to endure in the pursuit of weight loss and body acceptance:

my body was just deteriorating because it was working harder, but with less food. It's a sign that everything was basically just shutting down. I'd completely lost control of it [body], yet still thought it was just something I had to go through, because the ultimate aim is a certain weight or look

### "Rock bottom": a psychological warzone

All athletes reported negative psychological consequences associated with RED-S, ranging from initial increases in *irritability*, due to a preoccupation with food and exercise, to helplessness and despair. Over time, *withdrawal* from social situations (particularly those involving food) and intimate relationships (attributed to poor self-confidence or loss of libido) led to feelings of disillusionment. Symptoms of *depression* were reported by the majority of the sample, with three athletes reporting clinical diagnoses, and others comparing periods of intense sadness to reaching "rock bottom": "When you get to that breaking point... you have no energy at all and you're so sad, and that's when everything crumbles down" (Participant 2). *Anxiety, worry and concern* about health and performance were also described, with several participants articulating a sense of feeling "trapped" in their own minds: "every time something aches, it's a stress fracture (laughs)... in my head... I think the added pressure of an elite environment heightened everything" (Participant 7). Participant 1 echoed this heightened state of awareness surrounding LEA and its

impact on his physical and psychological wellbeing: "for me it's massive, my body is very sensitive to it and I can feel really anxious if I don't take in what I need. It seems to be a daily thing, so it can go from bad to worse in literally a day because of something I have or haven't eaten". This mounting negative emotion often resulted in conflicting thoughts and beliefs:

I've just wanted to get out of my own head... I just wish I could just be 'me' when I was before this happened and be like "yeah what would you actually like to eat?"... not what I think I should eat... and it's really hard, those lines are blurred (Participant 11)

### "Trapped": a cycle of disordered eating and compulsive exercise

Although the onset of RED-S appeared to occur inadvertently for some, a universal pattern of under-fuelling and over-exercising was reported during RED-S across the sample: "the further I was into it, the worse I got... the worse decisions I was making, because of the cycle I was in" (Participant 8). All athletes reported either a medically diagnosed ED ( $n = 4$ ), or self-reported ED/DE ( $n = 8$ ), although perceptions of whether these preceded or succeeded the onset of RED-S were ambiguous and varied between individuals. Conscious efforts to reduce energy intake through *restrictive eating* habits were described, such as skipping mealtimes, avoiding particular food groups (e.g., carbohydrates or fats), and *compensatory behaviours to counter energy intake*, (e.g., laxative use and purging). All athletes commented that their exercise attitudes and behaviours during RED-S were "unhealthy" or "excessive", although rarely acknowledged this at the time, instead believing their dedication to training was purely beneficial. A *transactional relationship with food and exercise* was also prominent, with eating viewed as a reward for gruelling exercise, and sporting injury regarded as justification for further food restriction. The experience of sport-specific training transitioned

**Table 3.** The subjective experience of RED-S.

Example raw data codes	Sub-theme	Theme
We are all veterans of the MRI machine and DEXA scan; I got a metatarsal stress fracture and then the tibial stress fractures started, of which I've had three	Bony stress injuries	A body thrown into disarray
I hadn't been having those [periods] for years; I stopped getting my period and it scared me; periods were out of whack	Menstrual dysfunction	
I felt really slow and lacking energy; there could be days where I'd go out the door and feel I'm sprinting, but I'm barely running anywhere because I'd just run out of energy really	Fatigue, weakness, reduced energy	
My guts were a complete and utter disaster; I'd get the worst stomach cramps and vomiting and bloody diarrhoea	Gastrointestinal health	
I became anaemic; seriously low ferritin levels; took iron tablets and performance improved	Haematological health	
I can feel shaky and cold and sweaty; I was cold all the time	Thermoregulatory issues	
I had really low oestrogen ... well literally no oestradiol; my thyroid hormone levels were dire	Endocrine dysfunction	
My immune system is shocking; I think I've had every disease or illness going	Immunological health	
A lurking panic; constantly anxious of further injury;	Anxiety, worry, and fear	A psychological warzone
Going down the anxiety/depression spiral; something weighing me down	Depression	
Complete and utter desperation; I was at breaking point;	Vulnerability	
When people would kind of, try to force me to do something that I didn't want to do, especially around food I would get very irritable ... I just wasn't a very nice person	Irritability	
Withdrawn from a lot of social situations; feeling detached and different to others	Withdrawal	
Right "I won't eat carbs"; only eating what I thought was healthy; intermittent fasting; scheduling a run deliberately over lunchtime so that I wouldn't want then to have lunch	Restrictive eating	A vicious cycle of disordered eating and compulsive exercise
I had to rest but I just cross-trained like a demon; on the elliptical for hours every day in the gym, weightlifting, swimming; sweat dripping off; going in harder to hurt yourself;	Exercising through injury or illness	
Running to control calorie intake; compensating with exercise if planning to eat more; I purge sometimes after a session if not feeling great physically or annoyed at the session	Compensatory behaviours to counter EI	
I was greedy so I couldn't eat; two hours on the elliptical it's not the same as running so you don't deserve the recovery food	Transactional relationship with food	
Couldn't go a day without running; I'd ride in the morning, gym at lunchtime, run in the evening; going to the gym every single day; an unhealthy relationship with exercise	A compulsion to exercise	

EEE = exercise energy expenditure; EI = energy intake

from being performance-focused, and enjoyable, to an obsessive and habitual pursuit, characterized by a *compulsion to exercise* and *persistence through serious injury or illness*:

"Exercise then became punishment really. I just used to, well, whip myself with it. I think I'd got self-destruction down to a fine art by then, so it was basically self-harming" (Participant 12)

### "Recovery" from relative energy deficiency in sport

A notable finding was the considerable heterogeneity in subjective appraisals of: progress towards, or successful attempts in overcoming RED-S; individual definitions of "recovery"; and the personal meaning attached to this concept. Seven athletes (58%) referred to themselves as "recovered" from RED-S, and the remaining five (42%) identified as still experiencing RED-S at the time of interview. Despite this, all athletes expressed a perceived vulnerability to experiencing inadvertent LEA and/or psychological distress while attempting to maintain optimal EA, with the notion of "long-term recovery" relying on an ongoing "battle" to manage this distress:

It's like you have two sides to your brain: the irrational and rational side, and it's being able to decide which one is actually correct. You know the rational side is there but in moments where you're really stressed out you just forget about it (Participant 2)

The following sub-sections describe the contexts influencing efforts to overcome RED-S, as well as the mechanisms that facilitated and inhibited self-defined "recovery" (Table 4).

### Recovery contexts

Three contexts were reported to influence individual "recovery" progress: **significant others**; **sporting context**; and **health as wealth**. Athletes with supportive and encouraging *personal relationships and professional support* reported more frequent success in improving EA, whilst those lacking such support continued to engage in harmful behaviours. Similarly, *sporting culture and demands* were beneficial for some athletes: "I thought, right 'do you want to be able to run a marathon, or do you want to go into hospital?'" (Participant 6). However, this could also be psychologically "triggering" for others: "I want my running to get better but my brain thinks being my natural weight I'd be too big to run well" (Participant 11). In many cases, however, it was not until a state of "rock bottom" was reached that the *motivation to improve psychological and/or physical health* was activated:

'everything had reached a head ... it was all out in the open, I was being monitored ... I was just at that point where I didn't want it to be anymore' (Participant 12)

### Facilitative recovery mechanisms

Mechanisms facilitating "recovery" from RED-S encompassed gradual improvements to EA, characterized by *reductions in exercise energy expenditure* and simultaneous *increases in energy intake* (**physiological mechanisms**) and overcoming mental conflict (**psychological mechanisms**): "I was training very, very little and I just ate as 'normally' as possible" (Participant 8). Some described how *improved nutritional*

*knowledge* acted as a “lightbulb moment”, after which they began to make sense of their experiences and implement behavioural change. Others admitted being well-informed of the dangers of LEA/RED-S already, but had to *challenge* prevailing *ED/DE attitudes and beliefs* to improve EA. Significant others were viewed as *positive role models* for many, providing further encouragement for behavioural change:

My boyfriend eats a hell of a lot of food ... and he'll pick me up on it [not eating enough] and just say 'eat everything that you feel you need to eat, and if you're hungry, just keep eating (Participant 3)

Furthermore, athletes who sought professional advice from a dietician or nutritionist reported progress in their “recovery”, as it had helped them to identify their personal energy requirements, understand the detrimental impacts of LEA, and develop practical steps to facilitate improvements in EA.

### Inhibitive “recovery” mechanisms

Although several athletes demonstrated an awareness of the harmful nature of their behaviours, numerous strategies were employed to reduce the negative emotions associated with engaging in them (e.g., denial to reduce feelings of shame), which encouraged the continuation of RED-S. This resulted in a **perpetuation of onset mechanisms**, including *restrictive eating practices*, maintenance of a *high training load and physical activity level*, and persistent *perceived need for control*. The majority of athletes who sought professional advice from general practitioners, sports physicians, and other medical staff regarding the implications of RED-S (e.g., menstrual dysfunction, depression), reported a *lack of professional support and information*. Many expressed frustration and despair at the advice, or complete lack thereof, and reported feeling dismissed and unworthy of support, which further legitimized their unhealthy behaviours:

I was like “no, I wanna get help”, but when I've been to the doctors about it, I'm not a low enough BMI ... it just made me feel really helpless because nobody wants to help me, but people are telling me I've got a problem (Participant 11)

Other perceived barriers cohered around interactions between *trait expression* and *social comparison*, which prompted athletes to downplay the severity of their condition: “In my mind, I'm bigger or the same size as everyone else who's running, so I can't possibly have a problem because I'm not thin” (Participant 9). These mechanisms were reported as ongoing difficulties, even for athletes who considered themselves “recovered” from RED-S, as they continued to navigate psychological distress elicited by decisions about EA behaviours.

## Discussion

The aim of this study was to qualitatively explore RED-S in endurance athletes. By acquiring rich, detailed insights into the subjective experience of the condition, through in-depth interviews, the current study sought to address a paucity of qualitative inquiry into RED-S. The findings contribute novel insights into the complex psychological and physiological interactions underlying the onset, experience, and efforts to

overcome RED-S, and, in turn, provide more elaborative insights into associations between markers of RED-S (e.g., energy intake, exercise energy expenditure) and psychological factors (e.g., DE/ED, exercise dependence) observed in recent cross-sectional research (Ackerman et al., 2019; Torstveit et al., 2019).

The present study provides important insights into the contexts and mechanisms that underlie the onset of RED-S in endurance athletes, including the likely occurrence of inadvertent LEA, which has been under-researched in sporting populations (Reed et al., 2014). A key finding was that while the onset of RED-S was associated with significant increases in training load that were not matched by adequate energy intake for the entire sample, half of the participants explained that such an imbalance between training and adequate energy intake was unintentional to begin with, and that the potential consequences of this were not understood at the time. In each of these cases, a state of LEA resulted in initial physiological outcomes (e.g., reduction in body mass and/or fat percentage) that were positively appraised, perpetuating the cycle of LEA behaviours, and eventually contributing to the reported onset of DE/ED and presentations of RED-S. This finding that inadvertent LEA preceded DE/ED onset aligns with previous research in female athletes who experienced rapid unintentional weight loss prior to developing an ED (Arthur-Cameselle et al., 2017) and provides new insights into the interactions between LEA and DE/ED, from the perspective of those with direct experience of these phenomena.

The symptoms of deteriorating physical and psychological health reported by participants when experiencing RED-S reconciled with many of the health and performance effects proposed by the RED-S conceptual models (Mountjoy et al., 2014). A multitude of impairments was described, including: gastrointestinal; reproductive; cardiovascular; and metabolic dysfunction; and factors contributing to a decline in sporting performance, which predominantly consisted of bony stress injuries, a noticeable reduction in energy levels, and perceived endurance capacity. Moreover, the findings illustrate that the psychological effects of RED-S can extend beyond the sporting domain, with difficulties reported by participants in their everyday lives and overall psychosocial wellbeing. In turn, the findings shed further light on the proposition that psychological factors can precede RED-S and be caused by RED-S, as depicted by the bidirectional arrow in the RED-S health model (Mountjoy et al., 2014). While recent research qualitatively explored the complex biological and sociological interactions in the presentation of LEA and RED-S (Thorpe & Clark, 2020), the current study develops and extends this understanding by offering novel insights into the psychological underpinnings and consequences of RED-S, as well as interactions with physiological symptoms. The current findings are congruent with past research identifying the high prevalence of DE/ED, compulsive exercise, and LEA among athletes in endurance and other lean-focussed sports (e.g., Melin et al., 2015). We extend this understanding, however, by identifying how specific, maladaptive eating and exercise behaviours resulted in a multitude of physiological and psychological impairments, and how these behaviours perpetuated RED-S by creating a psychological barrier to increasing and sustaining adequate EA. This provides support

**Table 4.** Contexts and mechanisms influencing “recovery” from RED-S.

Example raw data codes	Sub-theme	Theme	Category
I was really open with my husband about what was going on in my head because he just initially thought I was like really healthy	Personal relationships	Significant others	“Recovery” contexts
My nutritionist has encouraged me to eat more, being put in touch with her [dietician] was the impetus to change	Professional support		
In that community especially where there’s a lot of like pride with people saying “well I did my twenty-mile training run on only water” ... so then me *laughs* being me, I went and I ran the marathon and literally just drank water	Sporting culture and demands	Sporting context	
I ended up with a metatarsal stress fracture by July and that was when I really realized that things had to change	Motivation to improve physical health	Health as wealth	
You have to reach rock bottom before you get better I think, to force change	Motivation to improve psychological health		
I’d kind of looked at slowly increasing my portion sizes and trying new foods	Increasing EI to account for EEE	Physiological mechanisms	Facilitative “recovery” mechanisms
So now I actually tell myself “right, you’re not going to go for a run today because you just need to rest, because work’s been so stressful	Decreased training load/PA		
I worked with a dietician to actually understand, well “what do I eat?”. Because, I think the biggest struggle in recovery is like “how do I eat?” ... we don’t know how to eat	Improved nutritional knowledge	Psychological mechanisms	
Okay, I’m running further, and I’m eating more, and I’m enjoying it, so trying to mentally get in my head that this is a good thing	Challenging ED/DE attitudes		
Mum has never been on a diet she’s the most chilled person around food, she has cake every single day, she’s a normal weight because she exercises, but not because she’s crazy, like me	Positive role models		
I had to train every single day and I wasn’t refuelling after each session	Restrictive eating practices	Perpetuation of onset mechanisms	Inhibitive “recovery” mechanisms
I had to I had to rest but I just cross-trained like a demon	High training load/PA		
I’m so scared of losing control and looking normal. It sounds so weird, but yeah looking and being normal even though that’s a fear, it’s a want too ... I don’t know it’s so weird	Perceived need for control		
It feels like it’s decisions that I made at 16 or 17 that I’m sticking by you know and why am I still doing that? It feels ingrained ... very hard to change	Trait expression		
So the Doctor I went to see I just don’t think he took it very seriously ... he actually, kind of made me feel like I was kind of making stuff up	Lack of professional support and information		

DE = disordered eating; ED = eating disorder; PA = physical activity; EEE = exercise energy expenditure; EI = energy intake

for the proposed reciprocal nature of psychological health in the RED-S conceptual model (Mountjoy et al., 2014).

Findings in the current study not only suggest that the psychological consequences of LEA may indeed precede or result from RED-S (Mountjoy et al., 2018), but offer evidence to suggest that the psychological impairments can also prolong and exacerbate the syndrome. During efforts to overcome symptoms of RED-S, participants explained how behaviours required to initiate improvements and move towards recovery could elicit psychological conflict. The emergence of psychological conflict could be explained by cognitive dissonance theory (Festinger, 1957), which postulates that individuals experience dissonance when holding two sets of values, ideas, and/or beliefs that are not logically consistent or consonant with each other. Past research within sport and exercise psychology has demonstrated how cognitive dissonance can arise when individuals hold conflicting values and beliefs that threaten the integrity of their self-concept (S. M. Burke et al., 2008), or that are contrary to internalized societal attitudes (Stice et al., 2003). Our findings suggest similar experiences of dissonance during attempts to reinstate EA, which were triggered by a paradoxical desire to overcome RED-S by increasing energy availability, whilst simultaneously maintaining a compulsion to continue harmful practices that inhibited personal progress towards recovery. While cognitive dissonance could hinder efforts to recover from RED-S, the findings suggest that social support plays an important role in the path to recovery from RED-S. Furthermore, due to an evident lack of professional support and information reported within the

current study, it is vital that all members of the athletic milieu recognize the important role they can have in cultivating a supportive environment that encourages athletes to adopt appropriate nutrition and exercise practices for optimal health.

### Strengths, limitations, and future directions

By qualitatively exploring the experience of RED-S in information-rich cases, this research has provided novel insights into the complex interactions between contexts and mechanisms contributing to the onset of and recovery from RED-S. Whilst representativeness and statistical generalizability were not key judgement criteria for this qualitative study, naturalistic and analytic generalizability (Smith & McGannon, 2018) could be appropriate criteria. As such, the strength of the current study is that findings may resonate with the experiences of other sport and exercise participants who have experienced or are experiencing RED-S. A further strength was the methods used to enhance trustworthiness. As with any research, this study has limitations. First, there is potential for self-selection sampling bias given that participants expressed interest in sharing their experiences of RED-S. Second, the sample predominantly comprised sub-elite, female, endurance athletes, with only limited representation from male athletes. Given that male athletes may feel stigmatized towards disclosing issues traditionally associated with young girls and women (e.g., Triad and DE/ED; Gulliver et al., 2012), there is a fundamental need to explore and address existing sociocultural pressures within the sporting context, which may otherwise contribute to their continued

neglect within LEA research (Bratland-Sanda & Sundgot-Borgen, 2013). Finally, as both RED-S and “recovery” were self-identified by participants, it remains unknown whether objective measurements would have corroborated these assertions.

Based on findings and limitations in the current study, a number of avenues for future research are suggested. First, researchers investigating RED-S could continue to consider the use of qualitative methods to enable the development of new insights into this phenomenon. Second, further research that recruits male athletes, extends beyond endurance sport, and seeks to explore inadvertent cases of RED-S within a larger sample, is warranted to ascertain whether these findings pertain to broader domains of sport and exercise. Third, given that the psychology of RED-S has received relatively little attention compared to physiological work, further research that investigates RED-S from a psychological and psychophysiological perspective is required. Finally, future research should also seek to develop greater understanding of “recovery” from RED-S, especially as such work could have important applied implications.

## Conclusion

The findings suggest that individuals with self-reported RED-S experience a complex psychophysiological condition, which may be initiated or exacerbated by a cycle of disordered eating and compulsive exercise. Consequently, it is recommended that future screening and prevention efforts consider the underlying mechanisms that may precede RED-S onset, and that physiological treatment strategies should not be extricated from psychological approaches to target DE and clinical ED. The current findings highlight the crucial role of nutritional and psychological support (e.g., dietitians and mental health professionals) for facilitating long-term “recovery” progress from RED-S. Furthermore, there is a need to develop and validate clinical education and prevention interventions that address psychological aspects of the syndrome and seek to prevent the occurrence, or recurrence, of behaviours that initiate LEA to begin with.

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