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Corresponding author:
David John Clayton;
Email: david.clayton@leicester.ac.uk

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Interpreting intermittent fasting physiology in the context of behaviour

David John Clayton[1,2], Tommy Slater[1,2] and Lewis John James[3]

[1]Leicester Diabetes Centre, University Hospitals of Leicester NHS Trust, UK; [2]Diabetes Research Centre, University of Leicester, Leicester, UK and [3]School of Sport, Exercise and Health Sciences, Loughborough University, UK

Abstract

Intermittent fasting (IF) is a popular diet strategy involving extended periods of fasting or marked energy restriction, interrupted by periods of unrestricted intake. Several protocols exist under the IF umbrella, differing in timing, duration, and whether they require complete fasting or permit limited energy intake during restriction periods. These factors affect physiological and behavioural responses to IF. This review considers evidence that common IF approaches produce distinct physiological effects, and how different temporal structures alter behaviours affecting energy balance. The clearest evidence for distinct physiological effects is from early time-restricted eating. By shifting food intake early in the day, well-controlled studies have noted improved glucose control independent of weight change. In contrast, the physiological response to modified fasting, permitting ~400–600 kcal/day during restriction periods, does not appear to differ meaningfully from continuous energy restriction, while some complete fasting protocols report greater fat-free mass loss. The clinical effectiveness of IF may depend more on how effectively the energy deficit is retained across repeated restriction and feeding cycles. Several IF studies report reduced physical activity and increased energy intake outside of restricted periods, attenuating the intended energy deficit. Appetite control, food reward, eating traits, and routines, may influence compensation, adherence, and individual variability in response. In summary, some IF approaches can achieve distinct physiological effects, but behavioural changes often mitigate these under free-living conditions. Future research should characterise achieved fasting and energy restriction, identify predictors of behavioural compensation, and explore how adherence can be maximised whilst achieving a fasting-like metabolic response.

Intermittent fasting (IF) is an umbrella term for dietary patterns that incorporate recurring periods of fasting or marked energy restriction alongside periods of unrestricted eating. In practice, restriction can relate to the timing of intake, the amount of energy consumed, or both[1,2]. It is often positioned as an alternative to continuous energy restriction (CER), which aims to create a modest but sustained daily reduction in energy intake[1,3]. Although CER remains the most commonly used approach for weight management[4], maintaining a daily restriction may be challenging for some individuals because it requires continuous adherence and dietary restraint[1]. In contrast, IF concentrates dietary restriction into specific periods of the day or week, which may offer a simpler framework based on when to restrict intake, rather than sustaining restraint every day[5]. The appeal of IF also stems from the prospect of additional metabolic over behavioural advantages to conventional dieting[1,3,6].

Most clinical practice guidelines do not currently endorse IF as a distinct weight management strategy[4]. In the UK, NHS guidance operationalises an energy deficit through portion size reduction and calorie awareness[7], broadly indicative of CER. This likely reflects heterogeneity in IF approaches and limited quality evidence on long-term effectiveness, acceptability, implementation, and safety considerations in clinical cohorts[4]. However, the evidence base is maturing in type 2 diabetes, with a recent commentary arguing IF could be offered as one of several evidence-based lifestyle options under supervision[8].

Recent large meta-analyses indicate that IF can produce weight loss and improvements in cardiometabolic outcomes compared to non-dieting control groups, whilst producing broadly comparable effects to CER[9–11]. There is also no clear evidence that IF leads to more adverse events than CER, but uncertainty regarding long-term effectiveness and weight loss maintenance remain[9]. On balance, the current evidence suggests that IF could be considered an alternative to CER, but there is very little evidence that IF would be a superior approach. An important caveat to this conclusion is the considerable heterogeneity in the approaches that are encompassed by the umbrella term intermittent fasting, which are difficult to capture in meta-analyses. This is currently a barrier to the synthesis and translation of research evidence.

This review examines whether common IF approaches create distinct physiological exposures relative to CER and considers how temporal structuring of energy restriction alters eating and physical activity behaviours to influence outcomes. By integrating physiological and

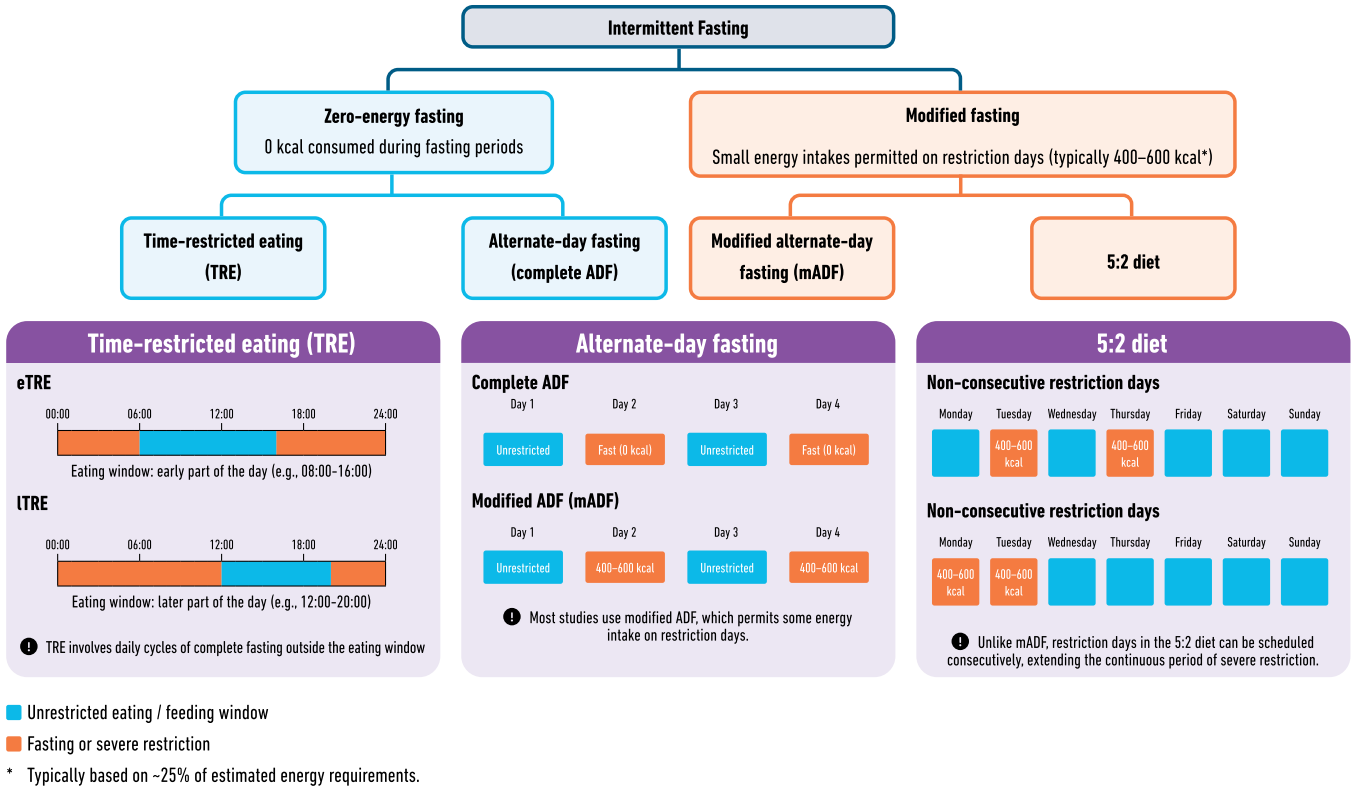


Fig. 1. Common types of intermittent fasting. Schematic representation of the commonly studied intermittent fasting protocols, grouped by whether they require zero-energy fasting (i.e. no energy consumed during restriction periods) or modified fasting (typically ~25% of energy requirements permitted during restriction periods).

behavioural responses, this review seeks to clarify how IF protocols influence energy balance and why outcomes vary between interventions and individuals.

What is fasting in the context of intermittent fasting?

A central challenge in interpreting IF research is how 'fasting' is operationalised across commonly implemented approaches. The approaches most commonly under IF are time-restricted eating (TRE), alternate-day fasting, and the '5:2' diet[1,2]. These can be distinguished by whether designated restriction periods require complete abstinence from energy intake or permit a limited energy intake. Zero-energy fasting protocols, such as complete alternate-day fasting (ADF) and TRE, involve no energy consumption during restriction periods, but still differ in fasting duration, frequency and timing. Modified fasting protocols, such as modified alternate-day fasting (mADF) and most 5:2 diets, typically permit up to 25% of energy requirements (~400–600 kcal) during restriction periods[1].

This distinction determines the fasting exposure achieved. Several of the proposed benefits, and potential drawbacks, of intermittent fasting stem from how long a given intervention extends the postabsorptive period. Complete ADF can considerably extend exposure to the postabsorptive state, whereas modified fasting may extend postabsorptive exposure to a variable degree that depends on the amount, timing and composition of energy consumed during restriction periods[3]. TRE extends the fasting period within each 24 h period and influences what time of day foods are consumed. The metabolic implications depend on how much the overnight fast is extended, and whether the eating window is positioned early or late in the day[12].

Ultimately, this means that two interventions may both be labelled as intermittent fasting while producing very different exposures to fasting, energy restriction, circadian alignment, and behavioural dietary constraint. This creates a conceptual problem for the field. If the effects of intermittent fasting are attributed to fasting *per se*, then it is necessary to establish whether fasting occurred, how long it lasted, and whether it constituted a meaningful physiological stimulus. Conversely, if the main effects arise from simply reduced eating opportunities and/or a requirement for intermittent rather than continuous adherence, then many intermittent fasting protocols may be better understood as a behavioural intervention designed to achieve energy restriction, rather than fasting interventions in the strict sense. This is essential for interpreting trial findings, informing dietary guidelines, and optimising intermittent fasting-based approaches. For the purpose of this manuscript, intermittent fasting is defined as dietary approaches that involve recurrent periods of complete or marked energy restriction, separated by periods in which unrestricted intake is permitted. Approaches are further distinguished as 'zero-energy fasting', where no energy is consumed during restricted periods, or 'modified fasting', where some energy intake is permitted. Additional distinctions are made according to the duration, frequency, and timing of restricted eating periods (Fig. 1).

Does intermittent fasting create a distinct physiological stimulus?

Postprandial metabolic responses usually persist for several hours after food intake, meaning that under a conventional three-meal-a-day pattern, most of the waking day, and potentially the first hours of sleep, are spent cycling between postprandial and early

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postabsorptive states[3]. This is characterised by exogenous glucose availability, increased carbohydrate oxidation, elevated insulin concentrations, and suppression of lipolysis and fat oxidation[13]. CER is commonly implemented within habitual eating patterns, with smaller or energy-reduced meals to achieve the intended daily energy deficit. In contrast, IF approaches aim to extend the postabsorptive period by manipulating meal timing and frequency, or by severely restricting daily energy intake within designated time windows[1]. This may induce a distinct metabolic profile compared with CER, including lower insulin concentrations, increased lipolysis, and greater mobilisation and oxidation of endogenous lipid-derived substrates, such as non-esterified fatty acids and ketone bodies[13,14]. Although a negative energy balance is the principal determinant of fat-mass loss, repeated exposure to prolonged postabsorptive states may enhance metabolic flexibility – the ability to switch between glucose and lipid oxidation depending on substrate availability – and improve insulin sensitivity[14]. Other proposed mechanisms include alignment of nutrient intake with diurnal metabolic and hormonal rhythms, and fasting-induced cellular repair and maintenance, although translational evidence in humans is limited[15]. Importantly, these effects are not ubiquitous across IF interventions and depend on the specific protocol, including whether designated restriction periods involve zero-energy or modified fasting, and where energy is consumed, the amount, timing and composition, as well as the degree to which prescribed fasting or restriction is maintained over time.

Time-restricted eating

The clearest evidence for distinct physiological effects of intermittent fasting comes from TRE protocols that align food intake to the early part of the biological day – known as early time-restricted eating (eTRE). Sutton *et al.*[16] demonstrated that restricting energy intake to a 6 h morning eating window (08:00–14:00) for 5-weeks improved insulin sensitivity, beta-cell responsiveness, blood pressure and oxidative stress, compared to an isoenergetic diet consumed over a 12 h window (08:00–20:00). These positive effects were achieved under energy intake-matched conditions without weight loss, indicating a mechanism of action independent of weight change. Supporting this, Jones *et al.*[17] reported that 2-weeks of eTRE (08:00–16:00) improved whole body insulin sensitivity and skeletal muscle glucose uptake compared to energy-and weight loss matched CER intervention in healthy men. Other controlled eTRE studies have reported improvements to glucose-related outcomes, including fasted glucose concentrations, glycaemic variability, time-in-range, and 24-h mean concentrations[18,19].

The mechanisms underlying these findings may reflect both extension of the overnight postabsorptive period and earlier nutrient intake, as insulin sensitivity is highest in the morning and declines over the course of the day[20–22]. Late TRE (lTRE) shifts the first caloric intake later in the day, prolonging the morning fasting interval. Studies that directly compare eTRE and lTRE suggest that nutrient intake timing may influence glycaemic outcomes, although these studies do not always isolate timing from changes in energy intake and weight loss.

In a 5-week three-arm study in healthy adults without obesity, eTRE (<8 h eating window; 06:00–15:00) reduced HOMA-IR compared to both lTRE (<8 h eating window; 11:00–20:00), and ad-libitum control, and reduced fasting glucose compared to control, whereas lTRE did not differ to control for either outcome[23]. In adults with overweight or obesity, eTRE (07:00–13:00) also improved mean glucose concentrations relative to lTRE (12:00–18:00), and reduced fasting insulin and HOMA-IR relative to control, whereas lTRE did not. Weight loss was similar between TRE groups, although eTRE resulted in greater fat-free mass loss than lTRE[24].

A large 12-week RCT comparing eTRE and lTRE in adults with overweight or obesity produced more equivocal findings. Glycaemic measures were more favourable with eTRE, but there were no between-group difference in cardiometabolic outcomes[25]. In this study, the median end of the eTRE window was 17:30, which is later than other studies (i.e. 13:00–16:00), which may have reduced the degree of early day circadian alignment. Most of these studies report similar weight loss between eTRE and lTRE, indicating that earlier eating windows may exert a positive influence on glycaemic outcomes independent of weight loss.

Observational evidence provides an interesting and complementary perspective. Regular breakfast omission is associated with poorer cardiometabolic health and greater weight gain[26]. Although these associations are vulnerable to confounding by broader diet and lifestyle factors, and breakfast omission and lTRE are not necessarily the same[27,28], these findings are consistent with the possibility that extending the morning fast and shifting intake later in the day may have consequences beyond its effect on daily energy intake alone.

Alternate-day fasting

In principle, zero-energy ADF provides the longest uninterrupted fasting period among the common IF approaches, with periods of 24–36 h without energy intake. Most trials, however, have used mADF, which permits around 25% of energy requirements to be consumed on restricted days. This approach was implemented after early studies reported challenges with the sustainability of complete fasting on alternate days[29], but does call into question whether the approach can truly be considered fasting.

Using zero-energy ADF, Templeman *et al.*[30] compared 3-weeks of ADF with energy-matched CER and ADF without net energy restriction in lean adults, isolating the effects of fasting and energy restriction. ADF without energy restriction did not reduce fat mass or improve cardiometabolic outcomes from baseline. When combined with energy restriction, ADF led to similar weight loss to CER, but less fat-mass loss, and proportionally more fat-free mass loss than CER. Most cardiometabolic markers, gut hormones, and adipose tissue gene-expression responses did not differ between groups. Ingersen *et al.*[31] similarly found no improvement in insulin sensitivity following 3-weeks of energy balanced ADF in men with obesity. A subsequent ADF plus energy restriction phase improved body composition and insulin sensitivity in men with type 2 diabetes. Whilst potentially limited by a short duration, these studies challenge the concept that fasting *per se* offers distinct physiological benefits over CER.

Several mADF trials have reported improvements in cardiometabolic risk factors, such as blood pressure, lipids, fasting insulin, or HOMA-IR, particularly in participants with obesity or metabolic impairment[1]. However, these findings should not be attributed to fasting-specific mechanisms, as mADF typically induces an energy deficit that leads to weight loss, and the prescription of energy intake on 'fast' days is variable[1]. The most informative trial on the long-term effects of mADF is Trepanowski *et al.*[32], who randomised 100 adults with obesity to mADF, CER or a no-intervention control for 12-months. mADF required

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alternating daily between 25 and 125% of energy requirements, whereas CER participants consumed 75% of energy requirements daily. Despite the considerable differences in pattern of intake over a 12-month period, there were no differences in body composition or cardiometabolic outcomes between mADF and CER. Taken together with the zero-energy ADF findings, current evidence suggests clinical effects are predominantly driven by weight loss resulting from the energy deficit achieved.

5:2

5:2 is a twice-weekly modified fasting approach. It differs from mADF in the frequency of restriction days in the week, and in some cases, how restriction days are distributed, which can be consecutive or separated by non-restricted days. However, like mADF, most evidence indicates no superiority over CER[10,33]. In the HELENA (Healthy nutrition and energy restriction as cancer prevention strategies) trial, 150 adults with overweight or obesity were randomised to two non-consecutive days per week consuming 25% of energy requirements (5:2), daily CER at 75% of requirements, or a control arm. Although there was a numerically greater weight loss after 12-weeks with the 5:2 approach, there were no differences found in weight loss, body composition, liver fat, or circulating cardiometabolic markers between 5:2 and CER[33].

However, physiological differences have been shown when restriction days are scheduled consecutively, rather than separated by refeeding days. Restricting intake to 25% of energy requirements on two consecutive days is likely to prolong exposure to low energy and carbohydrate availability, with low insulin concentrations and greater reliance on endogenous lipid oxidation[3]. Studies implementing 5:2 in this manner have reported greater reductions in fasting insulin and HOMA-IR than CER, despite similar weight loss[34–36]. Antoni *et al.*[36] also observed lower postprandial triglycerides and a trend toward lower c-peptide concentrations following matched 5% weight loss with two consecutive days of severe restriction per week, compared to CER. These findings suggest that the duration of the restriction period, rather than weekly frequency, may be physiologically important. However, these studies differ in absolute energy and carbohydrate intake and do not directly compare consecutive and non-consecutive approaches, while more recent work suggests that improvements in insulin sensitivity observed immediately after two days of severe energy restriction may not persist into subsequent non-restricted eating days[37]. As such, whilst consecutive days of severe energy restriction may generate transient metabolic benefits with the potential to improve aspects of metabolic health, the evidence for sustained superiority over CER remains limited.

Intermittent fasting as a behavioural intervention: implications for energy balance

In free-living settings, long-term studies rarely demonstrate additional benefit of IF over CER, for weight loss, body composition, or cardiometabolic risk factors[10,32,33,38,39]. This suggests its clinical effectiveness is more likely to depend on how these dietary patterns influence energy balance behaviours, as the energy deficit and resulting weight loss will account for much of the improvement in metabolic health.

CER requires daily adherence to a reduced energy diet, whereas IF changes the temporal structure of eating. For some, this may simplify decision making and reduce the burden of continuous monitoring and dietary restraint[5]. However, recurring periods of severely restricted and non-restricted intake create opportunities for compensatory behaviour, which may reduce the magnitude of the energy deficit achieved. The potential pathways of energy balance compensation and sources of individual variation are summarised in Fig. 2.

Modified fasting: from prescribed to achieved energy restriction

Maintaining a daily energy deficit is a well-recognised challenge with CER and gradual attenuation of energy restriction is a common obstacle to long-term weight loss success[40,41]. Zero-energy fasting protocols may be relatively simple to understand and self-monitor, because adherence is framed around a binary decision to eat or not eat. However, modified fasting approaches that permit up to approximately 25% of energy requirements to be consumed on restriction days, such as mADF and 5:2, still require individuals to quantify and limit energy intake during these periods. As a result, the intended severity of restriction and adherence may decline over time.

Long-term studies illustrate the distinction between prescribed energy restriction and achieved energy restriction. In a 12-month mADF trial, participants were prescribed 25% of energy requirements on restricted days and 125% on non-restricted days[32]. In practice, food diary records at 6-months suggested participants' intake was ~50% of energy requirements on restricted days and ~80% on unrestricted days, reducing the intended contrast between restricted and non-restricted intake days. Doubly labelled water also revealed that the overall deficit achieved was lower than the 25% prescribed, 21% with mADF, compared to 24% with CER[32]. This illustrates how the achieved pattern of restriction may differ substantially from the prescribed, reducing the absolute differences between mADF and CER, even when the overall energy deficit achieved is similar, and may partially explain why their outcomes are often comparable[10,32]. A related challenge is whether eating patterns are maintained beyond the active intervention period. During the 12-week HELENA study utilising a 5:2 modified fasting protocol, participants achieved, on average, 1.8 days of restriction per week, close to the two days prescribed[33]. Follow-up evaluations at 24 and 50 weeks in a subset of participants indicated that only ~33% and ~21% of respondents, respectively, were still completing two days of severe restriction per week[42]. These findings demonstrate the challenges to achieving a prescribed restriction with modified intermittent fasting protocols, particularly after intensive dietary support is withdrawn.

The energy deficit achieved across restriction and non-restriction periods also depends on the extent individuals compensate during non-restriction periods. Definitions of non-restriction periods vary, with some studies instructing a return to estimated energy requirements and others allowing *ad-libitum* food consumption. Acute studies of severe energy restriction have reported increased intake on the day after a 24-h period of restricted intake (25% of estimated energy requirements), compared to consuming an energy balanced diet[43,44]. One study also found that anticipating a forthcoming period of severe energy restriction could also increase energy intake in the preceding 24-h, indicating that compensatory eating behaviour may also begin before restriction itself[43].

In contrast, longer-term studies have not consistently reported the same degree of compensatory eating[32,42,45], although estimating intake from food diaries limits confidence in this data[46]. In women with overweight or obesity undertaking mADF,

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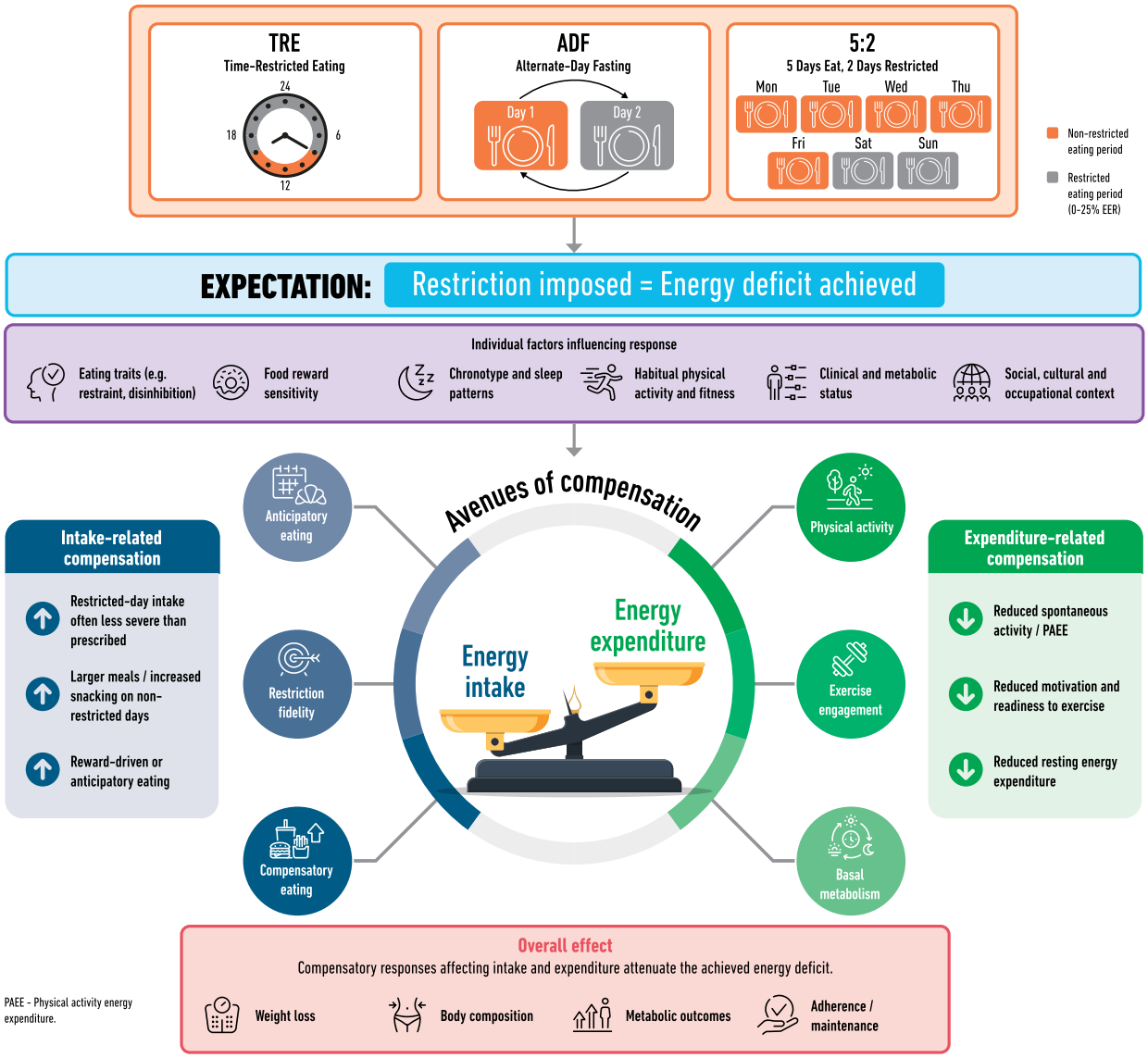


Fig. 2. How intermittent fasting influences energy balance. Conceptual map illustrating mechanisms of energy intake and expenditure compensation during intermittent fasting, alongside individual factors that may influence the magnitude of compensatory responses. These factors combine to determine the overall energy deficit achieved and downstream outcomes.

Beaulieu *et al.*[45] found no increase in self-reported intake on non-restricted days, despite greater hunger on restriction days. However, fewer participants achieved 5% weight loss with mADF than CER within 12-weeks (67 vs. 95%), despite a nominally larger energy restriction prescribed with mADF (38 vs. 25%). These findings suggest that the larger prescribed deficit with mADF was not consistently achieved, although the contribution of undetected compensatory eating remains uncertain.

Time-restricted eating: timing, compensatory eating and lifestyle challenges

Comparable considerations apply to TRE, although the restricted and non-restricted eating periods both occur within the same day. Shortening the daily eating window often reduces daily energy intake, and acute laboratory-controlled studies consistently show that daily energy intake is reduced with morning fasting compared to breakfast consumption[47–49]. However, compensatory eating behaviour after morning fasting differs, with lean adults typically increasing intake at subsequent meals[47,49], whilst no difference in subsequent energy intake was reported in adults with obesity[48]. Despite this, across six-weeks, daily energy intake was reduced with extended morning fasting in lean adults[50], but there was no difference in daily energy intake between morning fasting and breakfast consumption in adults with obesity[51]. Similar results were reported in the 12-week TREAT trial, where adults with overweight or obesity adhered to an 8-h lTRE protocol with all energy consumed between 12:00–20:00, or a control arm instructed to consume three meals per day between 07:00–22:00. This study found no between-group differences in weight loss or estimated energy intake[38]. Collectively these studies indicate that morning fasting/lTRE does not reliably produce a sustained energy deficit or greater weight loss, and compensatory eating later in the day may contribute in some contexts.

In contrast, eTRE retains morning food intake and restricts food intake later in the day, removing a different set of eating

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opportunities. Jones *et al.*[17] found that restricting food intake to between 08:00–16:00 in healthy adults led to a spontaneous ~400 kcal/day reduction in energy intake and produced modest weight loss from baseline after 2-weeks. Jamshed *et al.*[52] randomised adults with obesity to an 8-h eTRE diet (07:00–15:00) or a > 12-h eating window for 14-weeks. Participants in both groups were prescribed an energy-restricted diet and provided dietary counselling throughout the intervention. Weight loss after 14-weeks was 2.3 kg greater in the eTRE group, with weight-change modelling estimating a reduction in energy intake of ~215 kcal/day. These findings indicate that eTRE may be a particularly effective method for reducing energy intake and achieving weight loss.

A plausible explanation for the contrasting eating behaviour and weight loss findings between eTRE and lTRE is the time of day at which intake is restricted, and the foods that may consequently be omitted. lTRE retains evening intake, where meals and snacks tend to be more energy dense and discretionary intake more likely[12,53]. This is also the time of day associated with greater appetite and energy intake[53,54]. Together, these factors may mean that energy omitted through morning fasting is more readily recovered later in the day. eTRE removes that later eating opportunity, potentially reducing intake of energy dense foods typically consumed in the evening.

However, the apparent efficacy of eTRE must be balanced against its potential incompatibility with everyday life. Consuming the final meal of the day by mid-afternoon may conflict with work schedules and social commitments. Family and social occasions often occur in the evening and involve food, potentially limiting adoption and maintenance of this approach. Jamshed *et al.*[52] found that adherence to eTRE declined over the 14-week study, and only 28% of completers intended to continue with this eating schedule after the study had ended. Thus, whilst the physiological and behavioural responses to eTRE are compelling, the long-term acceptability of this approach remains uncertain.

Do appetite and food reward influence eating behaviour?

Appetite is a biopsychological system in which homeostatic signals, such as gastrointestinal, metabolic, and endocrine cues, interact with hedonic, social, and environmental influences to shape motivation to eat[55]. Periods of severe energy restriction during IF may influence appetite through several pathways, affecting tolerance of restriction and susceptibility to compensatory eating during non-restriction periods.

Across 17 RCTs, a meta-analysis found no clear evidence that IF altered subjective appetite ratings differently from CER[56]. However, most included studies used only isolated pre-and post-intervention measurements, providing little insight into appetite responses across repeated restriction and refeeding cycles. More granular data on mADF found hunger was greater during restricted than non-restricted days; average hunger was also greater during mADF than CER, and craving control improved less[45]. Although hunger does not always translate to altered eating behaviour, it can provide insight into the tolerability of energy restriction, with these findings suggesting that modified fasting may impose a greater subjective burden than CER.

Food reward encompasses the hedonic pleasure derived from eating ('liking') and the motivational value of food ('wanting')[57]. An acute fast has been shown to increase both liking and wanting for food, as well as the relative reinforcing value of snack foods, and ad-libitum energy intake, compared to a fed condition[58]. Similarly, extended morning fasting increases subjective appeal for high-calorie foods and activation of brain regions associated with reward, in response to food cues[59]. These responses may increase susceptibility to cue-driven compensatory eating during IF.

However, direct long-term evidence remains limited. In women achieving >5% weight loss through mADF or CER, explicit liking decreased after weight loss, wanting was unchanged, and there were no differences between dietary approaches[60]. Similarly, a 12-month 4:3 modified fasting intervention found greater reductions in binge and uncontrolled eating, compared to CER, but there were no between-group differences in reward-based eating scores[61]. Therefore, whilst appetite and food reward are plausible influences on adherence and compensatory eating during IF, the available evidence does not indicate that either is consistently altered differently from CER.

Movement as a compensatory response

Compensatory behavioural responses to fasting or severe energy restriction are not confined to energy intake. Resting metabolic rate (RMR) declines with weight loss, often more than would be predicted from body compositional changes alone (known as adaptive thermogenesis)[62], whereas diet-induced thermogenesis (DIT) will fluctuate across restricted and unrestricted eating periods. Neither appears to differ between IF and CER to an extent that could meaningfully affect total energy expenditure[63].

Physical activity energy expenditure (PAEE) is the most malleable component of energy expenditure and comprises both structured exercise, and non-exercise activity, such as walking, standing and spontaneous movements[64]. Reduced nutrient availability during zero-energy or modified fasting could lead to conscious or unconscious changes in physical activity, attenuating the energy deficit created by the diet[3]. Extended morning fasting reduced PAEE during the morning in both lean adults and adults with obesity, compared to a control condition in which a > 700 kcal morning meal was consumed before 11:00[50,51]. Extending the fasting period further in a well-controlled study, Templeman *et al.*[30] found that PAEE declined from baseline in participants undertaking ADF with net 25% energy restriction, whereas no within-group reductions were evident with energy-matched CER or ADF without energy restriction. Exploratory analysis indicated that PAEE responses were mostly evident during fasting periods, but a reduction was also detected during eating periods. An acute study also found reduced PAEE in the 24-h preceding a planned period of severe energy restriction, indicating that behavioural compensatory changes in PAEE can occur in anticipation of severe energy restriction[43].

Accelerometer-measured physical activity provides complementary evidence that movement patterns can change in response to severe energy restriction. Reduced light-intensity physical activity was observed during restricted days with mADF[45], whilst a separate study found an increase in sedentary time and reduced physical activity on restricted compared to non-restricted days[65]. However, neither of these studies found differences in average activity patterns or estimated energy expenditure, compared to CER[45] or control[65].

However, these responses are not universal. Two weeks of eTRE did not alter PAEE relative to energy-matched CER which may suggest that physical activity responses may depend on the temporal structure of fasting[17]. Overall, controlled studies provide evidence that fasting or severe energy restriction can reduce PAEE in some contexts. Such responses could compromise the energy deficit achieved by IF and could attenuate weight loss outcomes.

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Exercise behaviours, performance and affective responses

Regular exercise contributes to energy expenditure and can support weight maintenance, cardiometabolic health, and preservation of lean mass and physical function during weight loss[66–68]. However, these benefits depend on sustained willingness to engage in exercise. Fasting and severe energy restriction can alter habitual activity patterns, so could also influence the experience of, and motivation to undertake, planned exercise, with implications for diet and exercise adherence.

Evidence on the direct effects of intermittent fasting on exercise engagement is limited, but acute studies have demonstrated that morning or daytime fasting can impair endurance and resistance exercise performance[47,69–71], and may reduce motivation and readiness to exercise, as well as exercise enjoyment[69]. These behavioural responses indicate a mechanism through which fasting could influence exercise behaviour.

Longer-term studies indicate that strength and lean mass responses to resistance exercise performed alongside lTRE are similar to those observed with a non-restrictive eating pattern in trained adults[72,73]. This is broadly supported by a meta-analysis showing IF or CER can be combined with exercise without negatively affecting most physical performance outcomes relative to exercise alone[74]. This suggests acute performance decrements with fasting do not necessarily translate into impaired training adaptation. There may also be metabolic implications of exercising in the fasted state. Fasting increases lipolysis and endogenous lipid utilisation which is potentiated under an exercise stimulus[75]. This can lead to improved insulin sensitivity when performed over several weeks[76,77]. As such, whilst a decrease in exercise performance might be expected with fasting, this should be considered against potential metabolic benefits that could be incurred.

Whether acute performance decrements accumulate to influence long-term adaptation and compromise health benefits is unknown. Perhaps more importantly, impaired motivation, readiness, and enjoyment could compromise exercise engagement, as more positive affective responses to exercise are associated with subsequent physical activity participation[78].

Conclusions

Certain IF approaches can elicit physiological responses distinct from CER. Of the methods examined in this review, eTRE provides the clearest controlled evidence for improved glycaemic regulation, likely reflecting earlier nutrient intake aligning with endogenous circadian rhythms, and a longer daily postabsorptive period[12,16,17]. In contrast, modified fasting approaches typically produce a less sustained fasting exposure, and evidence for an enduring metabolic advantage over CER is limited[1,32,33]. Consecutive days of severe energy restriction may generate transient metabolic effects, but long-term effects on health outcomes are unclear[34–37].

Despite physiological differences, longer-term studies rarely report differences between IF and CER[9,10,32,33]. This may reflect how these approaches are implemented in free-living settings, where restricted-day intake during modified fasting often exceeds prescription, and compensatory changes in eating behaviour and PAEE may reduce the energy deficit further. Thus, alterations in behaviour may attenuate the translation of fasting-related physiological effects into meaningful long-term outcomes. Group-average findings also conceal individual variation in restricted-day adherence, compensatory intake, and movement responses. Some individuals may maintain a meaningful energy deficit across repeated restriction and refeeding cycles, whereas others compensate for much of the deficit created by fasting or severe energy restriction. Identifying behavioural responses that predict these divergent trajectories may help with improved outcomes with IF.

Overall, behavioural responses play a leading role in determining whether any physiological effects of IF translate into meaningful longer-term outcomes. Because of the distinct physiological exposures and behavioural demands imposed by dietary approaches grouped under the umbrella term of IF, pooling them may obscure meaningful differences and complicate translation of IF into dietary guidelines.

Future directions

Success with IF will depend on achieving restricted-day targets consistently without substantial compensatory changes to energy intake and/or expenditure. Individual differences in eating behaviours, eating traits, and food reward in response to fasting may help to identify people that are better suited to IF approaches than CER, but current evidence is limited. Studies in more diverse ethnic and clinical populations are also needed to better understand barriers and facilitators across groups and improve utility of approaches.

A key challenge is achieving meaningful metabolic exposure within feasible dietary patterns. Restricting carbohydrate during modified fasting may help to increase exposure to low-carbohydrate availability and replicate much of the postabsorptive state observed with fasting, without requiring zero-energy fasting[75]. Replacing some carbohydrate for increased protein on restricted days may support appetite control and adherence, while potentially limiting fat-free mass loss[79]. There is some interesting work already in this area[34,80,81], but strategies require direct testing, both alone and in combination.

Fat-free mass losses have been reported with IF[30,38,52], so it is important that future studies assess body composition more precisely. Dual-energy X-ray absorptiometry (DXA) estimates fat and fat-free mass but cannot distinguish skeletal muscle from other fat-free compartments, which is particularly relevant in shorter-term IF interventions, where changes in glycogen and hydration may contribute. Imaging, alongside strength and physical function measurements, would help to determine whether fat-free mass losses reflect skeletal muscle loss, and whether changes have meaningful consequences. The role of exercise alongside IF also warrants further investigation, particularly whether structured exercise can mitigate fat-free mass losses reported with some IF approaches. Future studies should also examine how regular exercise interacts with fasting to influence appetite regulation, compensatory changes in energy intake and physical activity, and ultimately weight loss.

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