Caloric Restriction, Basal Metabolic Rate, and Weight Loss: A Review

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ABSTRACT

Weight loss fundamentally requires an energy deficit, meaning caloric intake must fall below energy expenditure. A key component of energy expenditure is the basal metabolic rate (BMR) – the calories the body burns at rest to maintain vital functions.

It is well established that caloric restriction triggers compensatory changes in metabolism. As the body senses a calorie deficit, it often responds by reducing BMR, a survival mechanism to conserve energy. This phenomenon, sometimes termed “adaptive thermogenesis” or the “starvation response,” can make weight loss slower than predicted.

It has led to a common belief that one should never eat fewer calories than one’s BMR for fear of stalling weight loss or harming one’s metabolism. In this review, we examine the evidence on how calorie intake affects BMR and weight loss, whether very low calorie diets pose particular problems, and what the health implications are.

We find that while severe caloric restriction does reduce BMR, the overall energy deficit is still greater – resulting in faster weight loss – and that the notion one must always eat at least the BMR amount is not supported by clinical research. Key health considerations of aggressive diets are also discussed.

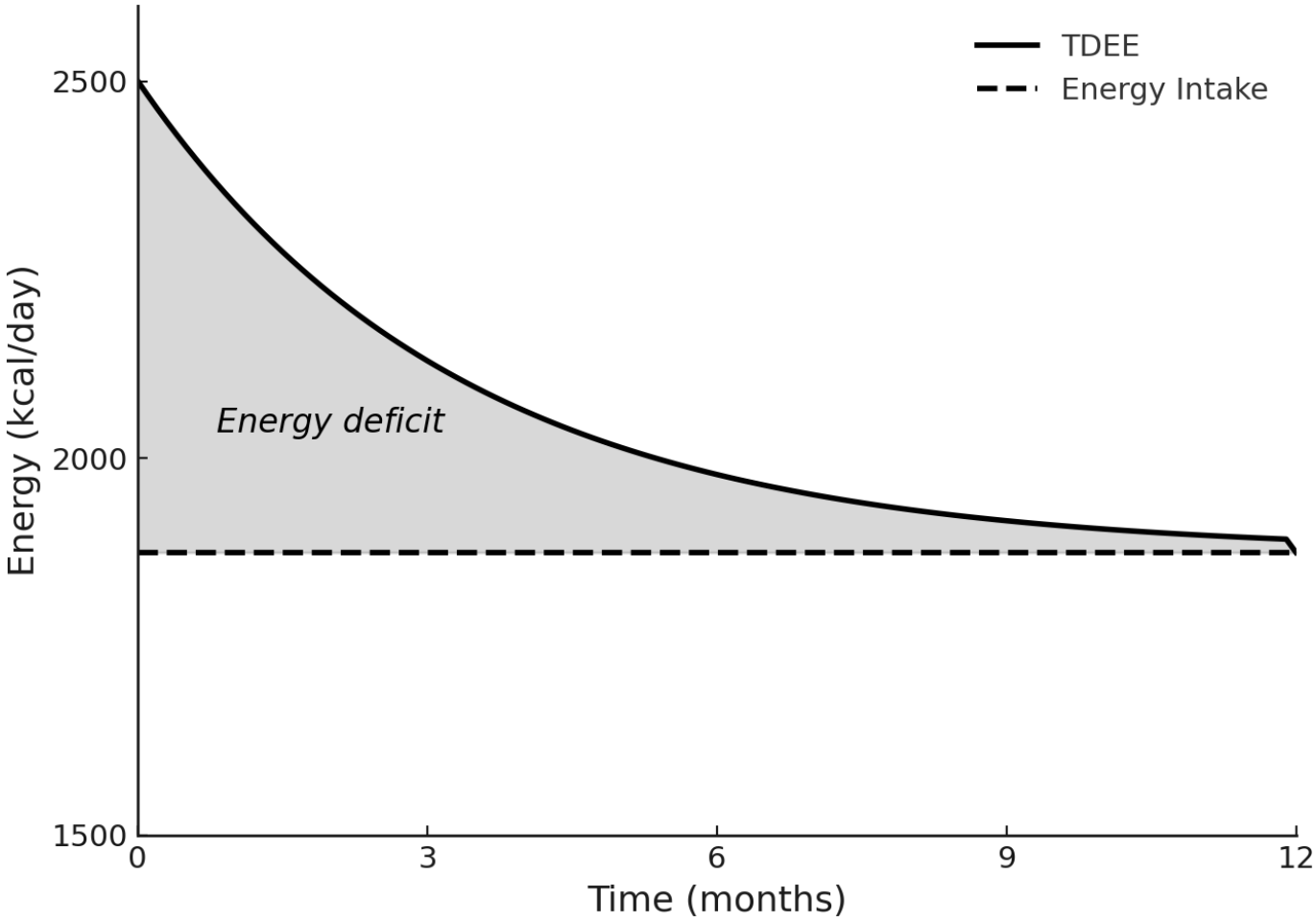
Subjects: Weight Management, **Keywords:** Obesity, Intervention , BMR

Caloric Restriction and Reductions in BMR

Cutting calories causes the body to lose weight, and a lighter body simply needs fewer calories per day to function. In addition, the body adapts by becoming more energy-efficient, further lowering the BMR than what weight loss alone would predict. In essence, reducing calories reduces BMR, meaning a dieting person will burn fewer calories at rest than they did before dieting. Numerous studies document this effect. In the classic Minnesota Starvation Experiment in the 1940s – a six-month semi-starvation study – young men consuming about half their usual calories experienced a 39% decline in resting metabolic rate (RMR) by the end of the trial, concomitant with a ~25% loss of body weight (Müller et al., 2015). Notably, roughly one-third of that RMR decline was beyond what could be explained by the loss of mass alone, indicating a true metabolic adaptation by the body to conserve energy (Müller et al., 2015). Modern weight-loss studies have observed similar, though often smaller, adaptations. For instance, participants in a televised weight loss competition (The Biggest Loser) who underwent intense caloric restriction and exercise (losing ~40% of body weight over 30 weeks) saw their RMR drop by about 23–25% – from an average ~2,600 kcal/day at baseline to ~2,000 kcal/day after weight loss (Fothergill et al., 2016). This RMR reduction was greater than expected from the change in body composition, again showing adaptive thermogenesis at work. Intriguingly, even six years later – after much of the lost weight was regained – the participants' RMR remained ~500 kcal/day lower than their pre-diet baseline, suggesting a long-lasting adaptation (Fothergill et al., 2016).

Importantly, metabolic adaptation occurs even with more moderate diets. In the CALERIE trials (Comprehensive Assessment of Long-term Effects of Reducing Intake of Energy) where non-obese adults followed ~25% calorie reduction for extended periods, RMR declined ~5–8% beyond what weight loss alone would predict (Most & Redman, 2020). Such adaptations have been observed as early as a few weeks into a diet. For example, after just 3–6 months of a 25% calorie deficit, sleeping metabolic rate was ~7–8% lower than expected, and total daily energy expenditure in free-living conditions was ~7–13% lower than expected, presumably due to both metabolic and behavioral adjustments (Most & Redman, 2020). These changes plateau over time as weight stabilizes. Ultimately, energy expenditure and intake reach a new equilibrium at a lower body weight, halting further weight loss. Figure 1 illustrates this dynamic: when a calorie-restricted diet is initiated, intake immediately drops, but energy expenditure gradually falls over weeks to months until it balances the new lower intake, resulting in a plateau. The gap between intake and expenditure (the energy deficit) narrows as BMR and other components of expenditure adapt to the calorie shortfall.

Figure 1. Trajectory of Energy Intake and Expenditure During Calorie Restriction

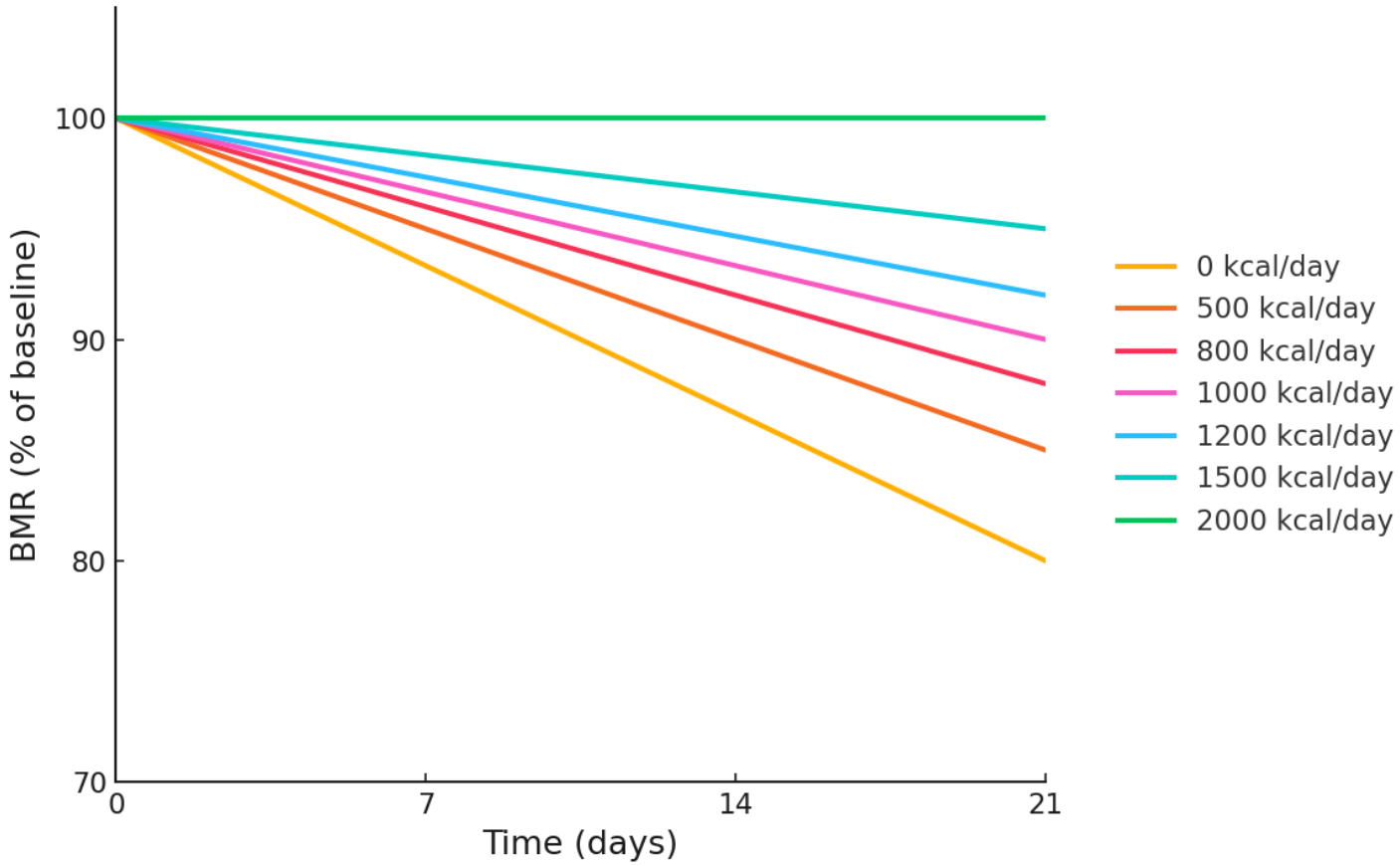


A simplified model showing the decline in energy intake and total daily energy expenditure (TDEE) over time following the initiation of a calorie-restricted diet (e.g., 25% reduction in intake). Energy intake drops immediately, while TDEE decreases more gradually due to weight loss and metabolic adaptation. The shaded area represents the cumulative energy deficit, which drives weight loss. Over time, this deficit shrinks as the body reduces energy expenditure, eventually reaching a new energy balance at a lower body weight—known as a weight-loss plateau. This adaptive reduction in TDEE has been documented in multiple human trials of sustained caloric restriction (MacLean et al., 2011; Most & Redman, 2020).

Physiologically, what causes BMR to drop during dieting? Part of the decline is simply due to having a smaller body (especially less fat mass and slightly less lean mass) that requires fewer calories. However, there is also a true adaptive reduction in metabolic rate per unit of body mass. This is driven by hormonal and neural changes during caloric deprivation. Circulating levels of leptin (a hormone from fat cells) plummet as body fat is lost, and thyroid hormones (like T3) and insulin also decrease, all of which collectively act to suppress metabolism (Martin et al., 2022). Muscles become more efficient, expending

fewer calories for the same work, and spontaneous physical activity (fidgeting, etc.) often declines subconsciously. Interestingly, recent research suggests that the loss of fat mass plays a bigger role than loss of muscle in the metabolic slowdown. In one 12-month caloric restriction study, individuals lost on average 7.2 kg of fat vs only ~1.0 kg of lean mass, and the degree of RMR decline was significantly correlated with how much fat was lost – whereas it was not strongly correlated with the small changes in muscle mass (Martin et al., 2022). This finding contradicts the common assumption that "crash dieting" causes dramatic muscle loss which then wrecks one's metabolism. In reality, adaptive hormonal responses from fat loss are a major driver of the BMR drop. In summary, when calories are reduced, the body does respond by lowering its metabolic rate – BMR may drop on the order of ~5–15% for moderate diets and even ~20–30% in extreme cases of prolonged or massive weight loss. This protective adaptation will slow the pace of weight loss over time. However, crucially, it does not completely counteract the calorie deficit – otherwise no further weight loss would occur. Even in studies with significant metabolic adaptation, weight loss continues until energy balance is reached at a lower weight.

Figure 2: Suppression of Basal Metabolic Rate (BMR) at Different Calorie Intakes



Decline in basal metabolic rate (BMR) expressed as a percentage of baseline over 21 days at different daily calorie intakes: 0, 500, 800, 1000, 1200, 1500, and 2000 kcal/day. Data are based on controlled studies

showing that greater calorie deficits result in greater and faster BMR reductions (Müller et al., 2015; Martin et al., 2022). By day 21, complete fasting (~0 kcal/day) can reduce BMR by ~20%, while diets around 800–1000 kcal/day show 10–15% reductions. At 1500–2000 kcal/day (close to maintenance for many), BMR remains relatively stable or only mildly suppressed. These patterns reflect both loss of mass and adaptive thermogenesis, where hormonal and neural signals reduce energy expenditure to conserve fuel during calorie scarcity (Most & Redman, 2020; Fothergill et al., 2016).

Is a Very Low Calorie Intake "Counterproductive"?

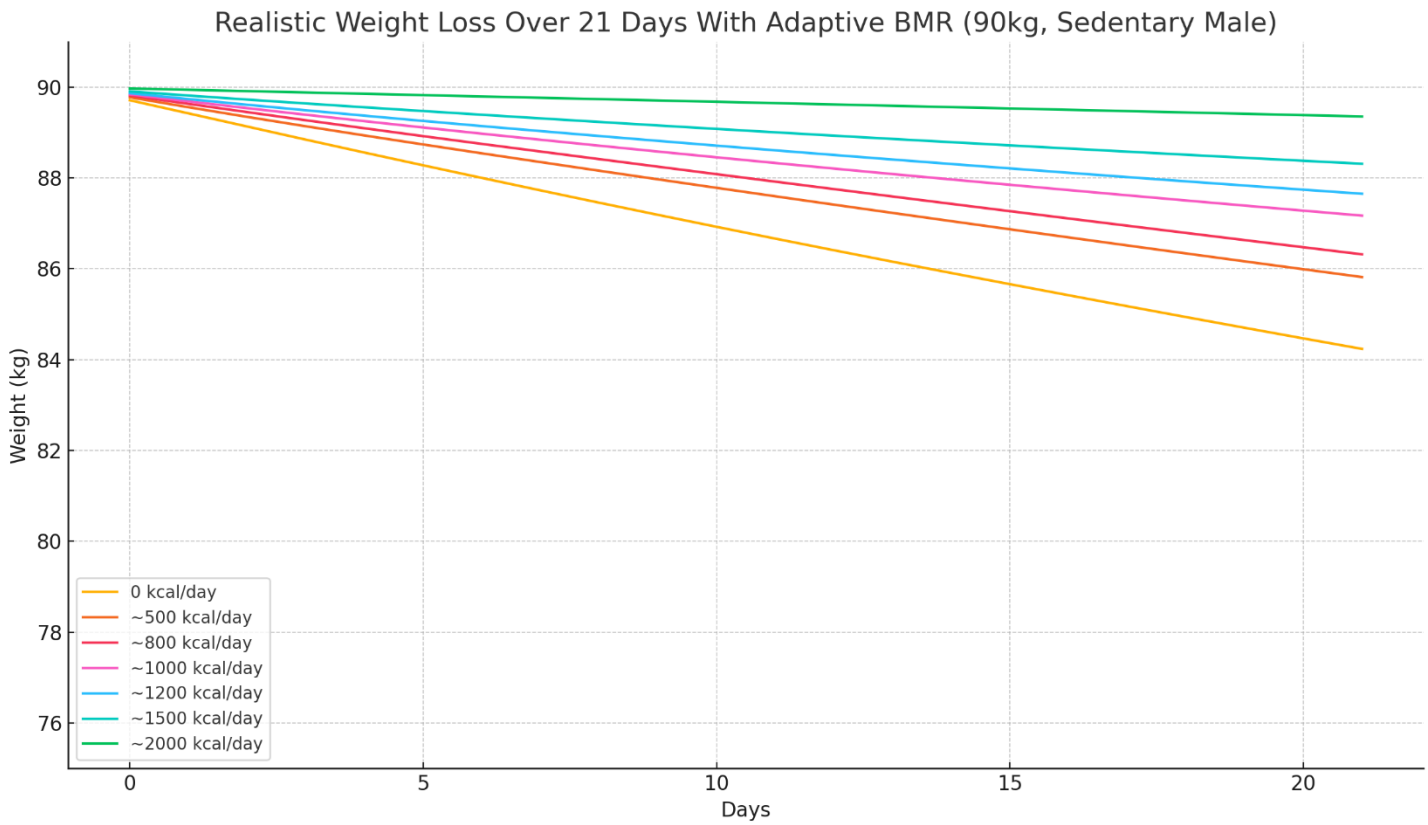
Given that caloric restriction causes metabolic slowing, an important question is whether more severe calorie cuts could backfire – an idea often popularly referred to as "starvation mode." The concern is that if one eats far below their BMR, the body might so dramatically reduce energy expenditure that little to no weight is lost (or even that health is harmed). Some diet advice claims one should never eat below BMR calories, suggesting that doing so halts fat loss. Scientific evidence, however, does not support the notion that going below BMR intake causes weight loss to stop. While extreme caloric restriction does trigger greater metabolic adaptation, it still produces larger net energy deficits and faster weight loss than more moderate deficits in the comparable time frame.

Consider clinical studies of very low-calorie diets (VLCDs), often defined as <800 kcal per day. Such diets are well below the typical BMR of an adult (which might be ~1400–1800 kcal/day for a healthy person). If "starvation mode" truly prevented weight loss, these diets would be ineffective. In reality, VLCDs consistently lead to substantial weight loss. For example, in a controlled trial, Wadden *et al.* (1994) assigned obese individuals to either a severe diet (~420 kcal/day liquid formula for 16 weeks, then 1200 kcal) or a modest diet (1200 kcal/day throughout). By the 26-week mark, the VLCD group lost about 21.5 kg on average, compared to ~11.9 kg in the moderate diet group (Wadden et al., 1994). In other words, twice as much weight was lost by eating well below BMR level for a period, despite any metabolic adaptation that occurred. This general pattern has been confirmed in multiple studies and summarized in meta-analyses. Tsai and Wadden (2006) found that across randomized trials, VLCDs produced significantly greater short-term weight loss than conventional low-calorie diets (an average of ~16% of initial body weight lost vs ~10% with more moderate diets over a few months). Clearly, the absolute rate of weight loss is higher when intake is extremely low – the body cannot fully compensate for a 1000+ kcal/day deficit by lowering BMR. Even though BMR falls, the energy gap remains larger in a VLCD than in a standard diet. For instance, an obese person might have a pre-diet expenditure of 2800 kcal/day. If they go on a 1200 kcal/day diet, their metabolism might eventually slow to, say, 2200 kcal/day, leaving a ~1000 kcal deficit initially. If instead they consume only 600 kcal/day, their metabolism might drop more, perhaps to 1900 kcal/day, but the deficit is still ~1300 kcal – larger than in the 1200 kcal scenario. The result is faster weight reduction. There is no magical threshold of calories (such as BMR level) below which the body ceases to burn fat. As long as there is a caloric deficit, weight loss will continue until a new equilibrium is reached.

It is important to note that metabolic adaptation does make it harder to continue losing weight as one gets leaner. The efficiency gained means one might plateau sooner than expected or need to further reduce intake or increase activity to keep losing weight. But this occurs with any diet, not just extremely low-calorie plans – it's a matter of degree. The idea that one should "never" dip below BMR intake likely stems from a misinterpretation of this adaptation. In practice, patients on physician-supervised very low-calorie regimens (400–800 kcal/day) do consistently lose significant weight (often 1.5–2 kg per week in the early stages) (National Task Force, 1993; Tsai & Wadden, 2006). Rather than being "counterproductive," such aggressive diets can be a powerful tool for rapid weight loss when appropriate. Indeed, one concern with severe diets is not that they fail to reduce weight – it's that they succeed too well initially, such that dieters must then transition to maintenance strategies to prevent regain.

A related misconception is that eating very little will cause the body to burn muscle instead of fat and permanently destroy one's metabolism, thereby sabotaging weight loss efforts. It is true that without adequate protein intake, a fast weight loss diet can lead to some loss of lean tissue. However, properly formulated VLCDs typically include sufficient protein (and sometimes resistance exercise) to minimize muscle catabolism. Research has shown that the proportion of weight lost as lean mass on a VLCD is usually relatively small (often 20–25% of total loss) and not drastically different from slower weight loss (where some muscle is also lost) (Tsai & Wadden, 2006). And as noted earlier, loss of fat (and the accompanying hormonal changes) appears to be a larger contributor to metabolic slowing than loss of muscle. The metabolic rate reduction is largely reversible as calories are increased after the diet (especially if weight is regained). There is no evidence that a short-term very low calorie diet causes any irreversible "metabolic damage." Metabolic adaptation is a normal, transient response to calorie deficit; once energy balance is restored (at a new weight), the adaptation diminishes. For example, in the study by Wadden et al. (1994), the group that lost ~21 kg on the VLCD did regain about half of that weight over the subsequent half-year (when they went back to a moderate diet), and by one year their mean weight loss was ~11 kg (virtually the same as the group that lost weight more slowly). At that point, their RMR would have risen again in line with the partial weight regain. Thus, "starvation mode" is not a metabolic brick wall but rather a sliding scale – the deficit might shrink over time, but a larger initial deficit still nets greater weight loss in the short run than a smaller one.

Figure 3. Realistic Weight Loss Over 21 Days at Varying Calorie Intakes with Adaptive BMR



Simulated body weight changes over 21 days in a sedentary 90 kg, 180 cm male consuming different calorie intakes (0, 500, 800, 1000, 1200, 1500, and 2000 kcal/day), accounting for dynamic reductions in basal metabolic rate (BMR) as observed in human trials. At very low calorie levels (e.g., ≤800 kcal/day), BMR decreases by up to 20% within three weeks, resulting in slowed—but not halted—weight loss (Müller et al., 2015; Martin et al., 2022). Despite these adaptations, lower intake levels still generate larger net energy deficits and thus greater weight loss than moderate diets (Most & Redman, 2020). By contrast, at or near maintenance levels (~2000 kcal/day), body weight remains stable due to near-zero energy deficit. This simulation illustrates how adaptive thermogenesis affects the slope of weight loss curves over time and reinforces that significant fat loss is achievable—even when metabolic rate declines—if caloric intake remains sufficiently below expenditure (Fothergill et al., 2016; Tsai & Wadden, 2006).

In summary, severely cutting calories will not prevent weight loss – quite the opposite, it accelerates it, although some of the advantage may be offset by metabolic adaptation and is often lost if weight regain occurs later. The key takeaway is that the common recommendation to never eat below one's BMR for fear of no results is misguided. So long as nutrient needs are met, creating a larger caloric deficit (even below BMR) will produce weight loss. One must simply be prepared for the body's compensatory responses and plan accordingly.

Health Aspects of Very Low-Calorie Intake

While consuming far below maintenance needs can be an effective weight loss strategy, it does raise important health considerations. The human body is remarkably adaptable and can function on a low energy intake for extended periods – but only if essential nutrients are provided and certain risks managed. The negative connotations of "starvation" come largely from historical or unsupervised contexts where nutrient deficiencies and extreme hunger caused serious harm. Modern medically supervised VLCDs are designed to avoid these pitfalls.

Nutritional adequacy is paramount. If someone simply stops eating or eats extremely little without regard to nutrients, they risk deficiencies in vitamins, minerals, electrolytes, and protein. This was tragically illustrated in the 1970s when a few individuals died after following a "liquid protein" diet that was very low in calories but also low-quality in nutrition. Today's VLCD protocols (often using formulated meal replacements or shakes) include protein, fatty acids, and a full complement of vitamins and minerals to ensure that although energy is low, the body's micronutrient requirements are met. In clinical trials of VLCDs (400–800 kcal) in obese patients, serious adverse events are rare when proper nutrition and medical monitoring are in place (National Task Force, 1993; Tsai & Wadden, 2006). Common side effects can include fatigue, cold intolerance (due to lower thermogenesis), dizziness or lightheadedness (especially if fluid and salt balance aren't maintained), and constipation. These are generally manageable. Many patients report the initial 3–4 days of a very low intake are the hardest (as the body shifts into ketosis and glycogen stores deplete), after which appetite often decreases and mood and energy can stabilize. Interestingly, some studies note improved mood and energy in patients once they are a few weeks into a VLCD, possibly related to ketosis or the psychological boost of seeing rapid progress.

One well-documented medical risk of rapid weight loss is gallstone formation. When weight is dropping quickly, the liver secretes extra cholesterol into bile and the gallbladder doesn't empty as frequently (since less food is coming in), promoting gallstone formation. The prevalence of new gallstones can reach about 10–12% of patients after 8–16 weeks on a low-calorie diet (Erlinger, 2000). The risk is higher with greater rates of weight loss (>1.5 kg per week) and with very low-fat diets (since some dietary fat helps prompt gallbladder emptying) (Erlinger, 2000). Many of these gallstones are asymptomatic, but some can cause pain or complications. To mitigate this, clinicians sometimes prescribe ursodeoxycholic acid during rapid weight loss to prevent gallstones, or ensure that a small amount of fat is included in the diet to keep the gallbladder active. Slowing the rate of weight loss (for example, not exceeding ~1.5 kg/week after the first few weeks) can also reduce gallstone risk. It's worth noting that obesity itself is a risk factor for gallstones, so an overweight person has elevated risk either way; the weight loss will ultimately reduce long-term risk even if it transiently increases risk during the active losing phase.

Another concern often voiced is the potential for loss of bone density or menstrual disturbances in women on very low-calorie regimens. Studies have shown that prolonged caloric restriction can modestly reduce bone density, likely due to both reduced weight-bearing and hormonal changes (lower estrogen, etc.). However, the effect over a few months of dieting is usually small, and resistance exercise plus adequate calcium/Vitamin D and protein can help protect bone health. Menstrual irregularities or temporary amenorrhea can occur in women if body fat drops to very low levels or due to hormonal adaptations, but for most individuals undergoing a VLCD for a limited period, these changes are reversible once adequate intake or weight is restored.

On the positive side, health benefits of aggressive short-term weight loss can be dramatic. In obese patients, a rapid loss of even 10–15% of body weight often results in improved glycemic control, lower blood pressure, and better lipid profiles. For example, very low-calorie diets are sometimes used in patients with type 2 diabetes to swiftly normalize blood sugar levels and even induce diabetes remission in some cases, under medical supervision. The swift reduction in visceral fat helps improve insulin sensitivity. Cardiovascular risk factors tend to improve as well with weight loss, whether rapid or slow, but patients often appreciate the quick relief from weight-related symptoms (like joint pain or sleep apnea) that a VLCD can provide within weeks. Psychologically, some individuals find a strict regimen easier to adhere to (removing food choices entirely) and are motivated by the rapid results, whereas others may struggle with the intensity of hunger or restriction. Thus, suitability varies by individual.

Metabolic health during and after a VLCD is an area of active study. Some researchers have noted that severe caloric restriction leads to larger drops in circulating leptin and thyroid hormones than more gradual diets, which could potentially increase hunger and fatigue. Appetite hormones like ghrelin (which stimulates hunger) can increase as body weight falls. Therefore, an individual coming off a very low-calorie diet might experience stronger hunger signals and a body primed to regain weight ("post-starvation hyperphagia") compared to someone who lost weight slowly – though this is not a universal rule. Support during the refeeding and maintenance phase is crucial. Exercise, particularly strength training, during weight loss and beyond can help counteract metabolic slowing by preserving lean mass and slightly boosting energy needs, and it also aids psychological well-being. As Hall *et al.* (2016) observed in the Biggest Loser follow-up, those who maintained greater weight loss after six years tended to be the ones who had a persistently slower metabolism – a testament to the body's push to regain weight, but also proof that maintaining weight loss is possible even with a slower metabolism if one adjusts lifestyle accordingly (Fothergill *et al.*, 2016).

Finally, it's important to highlight that caloric intake should not be chronically minimized to extremes without medical need or oversight. For individuals with mild to moderate excess weight, a balanced moderate caloric deficit may be safer and more sustainable, whereas VLCDs are typically reserved for those with obesity or specific medical indications

(and for limited durations). Chronic undereating can lead to eating disorders or other health issues. The focus should always be on a plan that is effective and sustainable for the individual. If a short-term very low-calorie phase is used to jump-start weight loss, it should transition into a longer-term maintenance strategy that the person can live with. With proper planning, the transient metabolic adaptations that occur with rapid weight loss are not dangerous – they are manageable changes that underscore the importance of a holistic approach to weight management (including diet, physical activity, behavioral support, and possibly medical therapies for maintenance).

CONCLUSION

In summary, substantial evidence indicates that reducing calorie intake will reduce BMR – our bodies inherently adapt to energy scarcity by conserving energy. The magnitude of BMR reduction depends on the size and duration of the calorie deficit, as well as the amount of weight lost, but even a 5–10% drop in body weight can produce a noticeable (~5–15%) decline in metabolic rate. This adaptive response does slow the pace of further weight loss, creating a moving target for dieters. However, the often-heard warning "never eat below your BMR" is not scientifically justified in terms of weight loss outcomes. While eating below BMR (for example on very low-calorie diets) causes a greater relative slowing of metabolism, it still yields a greater total energy deficit and therefore more fat loss than more modest dieting – at least in the short to medium term. The body cannot completely negate a large calorie gap; it can only partially compensate. Indeed, very low-calorie diets have helped thousands of patients achieve rapid weight loss, which can be particularly beneficial for improving obesity-related conditions.

That said, aggressive calorie restriction is a tool that must be wielded carefully. One should not equate the ability to lose weight faster with an absence of risk or difficulty. The metabolic adaptation accompanying large calorie cuts means that, when normal eating is resumed, weight regain is a real threat – reinforcing that long-term weight management requires ongoing attention to diet and lifestyle. There are also health considerations (such as gallstones, nutrient deficiencies, and hormonal changes) that must be managed through proper medical supervision and diet design. For these reasons, blanket recommendations arose cautioning against overly low intakes. However, when interpreted as an absolute rule forbidding any intake below BMR, this guidance misses the nuance. The critical point is ensuring adequate nutrition and a plan for maintenance, rather than focusing on an oversimplified calorie threshold.

In conclusion, the body's metabolic slowdown during dieting is not a sign of failure but an expected adaptive mechanism. Even though the body reduces its expenditure in response to calorie cuts, a lower intake still results in a greater net deficit and faster weight loss in well-controlled settings. The prevailing thought that one must never "go below BMR" is therefore misplaced. What matters more is how a low-calorie diet is implemented

and what comes after it. With appropriate nutritional support and behavioral strategies, even quite low calorie regimens can be safe and effective for weight loss. Ultimately, sustained success will depend on adapting one's lifestyle to the new metabolic reality – but no calorie restriction regime defies the laws of physics. Any diet that consistently induces an energy deficit will cause weight loss, and a larger deficit (even if below BMR) will generally cause a larger weight loss. Rather than fearing metabolic adaptation as an unbeatable barrier, we should understand it and plan for it. By doing so, we can dispel the myth of "starvation mode" and make informed decisions on the level of calorie restriction appropriate for each individual's goals and health, without clinging to an arbitrary calorie minimum.

Conflict of interest

The authors of this study are employees of Novogenia GmbH, a private commercial genetic laboratory that also funded this research. The scientific review focuses on aspects of product efficiency sold by the company.

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