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Original article

Variation and outcomes of liver-reducing dietary regimens before bariatric surgery: a national retrospective cohort study

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Abstract

Background: Liver-reducing diets (LRDs) are mandated prior to bariatric surgery, but there are no guidelines on their implementation.

Objective: To establish the variation and effectiveness of LRDs utilized in clinical practice.

Setting: A nationwide, multicenter, retrospective cohort study.

Methods: A total of 1699 adult patients across 14 bariatric centers in the United Kingdom were included. Multilevel logistic regression models were developed to examine factors predictive of 5% weight loss.

Results: Most centers (n = 9) prescribed an 800- to 1000-kcal diet, but the duration and formulation of diet was variable. Overall, 30.6% (n = 510) of patients achieved 5% weight loss during the LRD. After adjustment for preoperative weight, women had reduced odds (odds ratio [OR], .65; 95% confidence interval [CI], .48–.88; P = .005), while increasing age (OR, 1.01; 95% CI, 1.00–1.02; P = .043) and having type 2 diabetes (OR, 1.49; 95% CI, 1.16–1.92; P = .002) increased odds of 5% weight loss. A normal consistency food LRD (OR, .64; 95% CI, .42–.98; P = .041) and energy prescription of >1200 kcals/d (OR, .33; 95% CI, .13–.83; P = .019) reduced odds, while an LRD with a duration of 3 weeks (OR, 2.28; 95% CI, 1.02–5.09; P = .044) or greater increased odds of 5% weight loss.

Conclusions: There is wide variation in how LRDs are delivered in clinical practice, highlighting the need for an evidence-based consensus. Our findings suggest the optimal LRD before bariatric surgery contains 800 to 1200 kcals/d over a duration of 3 to 4 weeks. Further research is required to determine the optimal formulation of LRD and whether women may require a lower-energy LRD than men. (Surg Obes Relat Dis 2022; ■:1–7.) © 2022 American Society for Metabolic and Bariatric Surgery. Published by Elsevier Inc. All rights reserved. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Keywords: Liver-reducing diet; Low-energy diet; Very low-energy diet; Bariatric surgery; Nutrition; Preoperative optimization

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Obesity is characterized by excess adipose tissue, which can result in nonalcoholic fatty liver disease (NAFLD) due to the exaggerated synthesis and deposition of triglycerides in hepatocytes [1]. Body mass index (BMI) has a significant positive correlation with liver steatosis [2] and compared with normal BMI; obesity increases the risk of developing NAFLD by 3.5-fold [3].

The prevalence of NAFLD among patients undergoing bariatric surgery is reported to be as high as 81% to 90% [4,5]. NAFLD presents an operative challenge for laparoscopic bariatric surgery, as liver retraction is necessitated to gain access to the stomach, and therefore bariatric centers around the world mandate a short-term preoperative liver-reducing diet (LRD).

LRDs facilitate the depletion of glycogen and lipid stores in the liver, resulting in a reduction in liver volume and improved liver flexibility [6]. LRDs also result in rapid weight loss which reduces visceral adiposity [7], enabling improved access to the stomach. LRDs can affect patient outcomes through a variety of mechanisms, including reduction in surgeons' perceived complexity of the procedure [8], improved whole-body insulin sensitivity [9], and possible reduction in the risk of postoperative complications [10].

LRDs are supported by the Guidelines for Perioperative Care in Bariatric Surgery in the Enhanced Recovery After Surgery (ERAS) Society Recommendations [11], as there is a significant positive correlation between total weight loss and hepatic volume reduction during LRDs prior to bariatric surgery [8] and therefore weight loss is a pragmatic marker of liver volume reduction.

It is common practice for patients undergoing bariatric surgery to be supported toward a 5% weight loss in the immediate period before surgery, to reduce hepatic volume [12]. European Society for Clinical Nutrition and Metabolism Guidelines on Clinical Nutrition in Liver Disease [13] recommend low-energy diets as an effective intervention in achieving a weight loss at least 5% and a significant improvement in liver steatosis in NAFLD. Among patients undergoing bariatric surgery, a 5% weight loss during preoperative dietary regimens results in hepatic volume reductions of between 15.6% [8] and 23.0% [14].

A systematic review [12] synthesized the findings of 8 randomized controlled trials (RCTs) to examine the effectiveness of LRDs in achieving a 5% weight loss. LRDs of 700 to 1050 kcals/d over a minimum duration of 3 weeks supported the attainment of a 5% weight loss. However, definitive evidence-based conclusions were unable to be drawn from this study, due to the limited number of trials and the heterogenous nature of the LRD interventions.

There is high variability in how LRDs are delivered within and between multiple countries across the world [15–18]. This reflects the lack of conclusive evidence on the most optimal type, content, or duration of LRD [19], resulting in European [20] and US [21] clinical practice

guidelines being unable to make evidence-based recommendations on the delivery of LRDs. Hence, the aim of this study was to establish the variation in, and weight loss outcomes of, LRDs currently used in clinical practice across multiple bariatric centers in the United Kingdom (UK).

Methods

Study population

We conducted a UK multicenter retrospective cohort study examining weight loss outcomes from LRDs before bariatric surgery. An open invitation was sent to dietitians, inviting them to nominate their bariatric center to contribute data to the study. The invitation was sent to members of a closed online discussion forum (Google Group) for registered dietitians working in bariatric services in the UK. To participate in the study, centers were required to have access to patient records that detailed the prescribed LRD and weight before and after LRD at the individual patient level.

All adult patients (≥ 18 years of age) who underwent a primary bariatric procedure funded by the National Health Service (NHS) between January 1 and December 31, 2019, were eligible for inclusion. For adults to be eligible for NHS funded bariatric surgery in the UK, a supervised weight management program must have been undertaken for 6 to 12 months with support from a specialist multidisciplinary team (MDT) and have a starting BMI ≥ 40 kg/m² or between 35 and 40 kg/m² with an obesity-related co-morbidity [22]. Patients were excluded if LRD intervention or weight outcome data were missing from the patient records.

Data collection

Data were collected at the site level from existing patient records and included patient demographic (sex, age, ethnicity), type 2 diabetes (T2D) status, LRD intervention (prescribed energy intake [kcal]), formulation, duration, and whether patients could choose which diet they followed), and anthropometrics (weight, BMI) before starting the LRD and on the day of surgery, when the LRD ended. In UK clinical practice, patients undergoing bariatric surgery may experience short-notice surgery cancellations, leading to prolongation of the LRD. Therefore, any extension to the duration of the LRD was also recorded, including reasons. Data were anonymized by the participating sites before transferring the data to the lead researcher for analysis.

Weight loss was used as a pragmatic surrogate marker of liver size reduction. A $\geq 5\%$ weight loss is achievable via nutritional intervention and results in clinical improvements in hepatic steatosis [13] and, hence, the primary outcome was attainment of 5% weight loss on the day of surgery.

Ethical approval was granted by Coventry University Ethics Committee, Coventry, UK (P130160).

Data analysis

All analyses were undertaken using SPSS version 26. Descriptive statistics were used to explore individual patient characteristics and intervention factors associated with achieving 5% weight loss. χ^2 tests were used to explore associations between the different elements of the dietary intervention and the achievement of 5% weight loss. Since data were collected across several different bariatric centers, multilevel logistic regression models were developed to investigate factors predictive of 5% weight loss, adjusting for clustering, since patients are clustered (i.e., grouped) within centers.

In the first step, a null model was fitted to the data. Bariatric center was included in the model as a random effect since the likelihood ratio test statistic was significant at the 5% level. This indicates that differences between bariatric centers account for some of the variability in attainment of 5% weight loss before surgery. Individual level characteristics were then added as fixed effects to the model and removed one-by-one using a manual backward elimination approach if they did not achieve statistical significance based on a cut-point of $P = .05$. These included age (yr), sex (male/female), T2D status at baseline (yes/no), weight at baseline (kg), ethnicity and whether the diet was extended (yes/no). Finally, elements of the LRD were added to the model and removed one at a time according to the above strategy. These included daily energy prescription (kcal), recommended diet duration (wk), diet formulation, and whether the patient was given a choice of diet (yes/no). The choice of diet was effectively a bariatric center-level variable (level 2) since the bariatric centers in the study either gave patients a choice or not. The other LRD elements were almost level-2 variables, with very little within-center variability.

Results

Fourteen out of 55 NHS funded bariatric centers in the UK participated in the study. A total of 1817 patients were eligible of which 1669 were included in the analysis: 8.1% ($n = 148$) were excluded due to missing data (diet not recorded $n = 6$, baseline weight not recorded $n = 6$, surgery weight not recorded $n = 136$).

Baseline characteristics

The mean patient age was 46.8 years (standard deviation, 11.1). The cohort was predominantly female (79.4%, $n = 1325$) and White (81.9%, $n = 1367$). A total of 462 patients (27.7%) had T2D and the median BMI at baseline was 45.6 kg/m² (interquartile range [IQR], 41.3–51.1) (Table 1).

Dietary intervention

There was variation in the prescribed LRD between participating bariatric centers (Supplement 1). Most of the participating centers ($n = 9$) prescribed an 800- to

Table 1
Baseline characteristics of participants ($n = 1669$)

Characteristic	Value
Age (yr), mean (SD)	46.8 (11.1)
Male, n (%)	344 (20.6%)
Ethnicity, n (%)	
White	1367 (81.9%)
Black	60 (3.6%)
South Asian	50 (3.0%)
Other	62 (3.7%)
Unknown	130 (7.8%)
Diabetes, n (%)	
No diabetes	1207 (72.3%)
Type 2 diabetes	447 (26.8%)
Type 1 diabetes	15 (.9%)
Weight (kg), mean (SD)	130.6 (25.6)
BMI (kg/m ²), mean (SD)	46.8 (7.8)

SD = standard deviation; BMI = body mass index.

1000-kcal diet. No choice of diet was offered to patients in half of the centers ($n = 7$), and, at these centers, the main prescribed dietary formulations were milk only diet ($n = 2$), milk and yogurt diet ($n = 3$), and normal consistency food diet ($n = 2$). The remaining centers ($n = 7$) gave patients the autonomy to choose their LRD formulation, which could also include meal replacement formulations. The duration of LRD was standardized for all patients in 7 centers, regardless of patients' BMI, with 6 centers prescribing a 2-week duration and 1 center prescribing a 3-week duration. Across the other bariatric centers ($n = 7$), the duration of the LRD was dependent upon BMI, whereby patients with a higher BMI of ≥ 50 or ≥ 60 kg/m² were prescribed a longer duration of LRD, which ranged from 3 to 12 weeks.

Most patients undertook the LRD for the prescribed duration, but a small number of patients underwent a prolonged LRD ($n = 129$, 7.7%) for a median duration of 14.5 days (IQR, 7–28 days). Reasons for a prolonged duration of LRD were mainly due to rescheduling of surgery dates due to bed capacity or surgeon availability ($n = 106$).

Weight loss outcomes

The mean weight loss between baseline and surgery was 5.30 kg (95% confidence interval [CI], 5.06–5.54) and 510 patients (30.6%) achieved 5% weight loss (Table 2).

Results of the multilevel logistic regression model to investigate 5% weight loss are shown in Table 3. The null model showed that there was a significant random effect for bariatric center ($P = .039$), but this effect disappeared after accounting for characteristics of the patients and the LRD. After adjusting for weight before surgery, patient factors that improved the odds of 5% weight loss included increasing age, male sex, and having T2D. In particular, the odds of achieving 5% weight loss for women were around .6 times the odds for men after accounting for the

Table 2
5% weight loss by dietary intervention (n = 1669)

Dietary intervention	Total	Achieved 5% weight loss, n (%)	P value*
All	1669	510 (30.6%)	-
Choice of diet			<.001
Yes	682	280 (41.1%)	
No	987	230 (23.3%)	
Kcals			<.001
<800	65	20 (30.8%)	
800–1000	985	381 (38.7%)	
1000–1200	512	93 (18.2%)	
>1200	107	16 (15.0%)	
Formulation			<.001
Nonsolid food	1136	290 (25.5%)	
Food	227	68 (30.0%)	
Meal replacements	73	37 (50.7%)	
Meal replacements + food	233	115 (49.4%)	
Duration			<.001
1 wk	88	12 (13.6%)	
2 wk	1160	302 (26.0%)	
3 wk	194	76 (39.2%)	
4 wk	170	87 (51.2%)	
≥5 wk	57	33 (57.9%)	

* χ^2 test for independence.

other factors in the model (adjusted odds ratio [OR], .648; 95% CI, .479–.875; $P = .005$). Elements of the LRD impacting 5% weight loss included the diet formulation, prescribed energy intake, and the diet duration. Those on a normal consistency food diet were less likely to achieve 5% weight loss

compared with those on a liquid consistency diet (adjusted OR, .643; 95% CI, .421–.982; $P = .041$), and the odds of achieving 5% weight loss increased with weeks on diet, with 3 weeks or more showing significant benefit over just 1 week.

Table 3
Results of random effects logistic regression model (n = 1669)

Fixed effects	Coefficient	Adjusted odds ratio (95% CI)	P value
Intercept	-2.571	.076 (.019, .305)	<.001
Age	.011	1.011 (1.000, 1.022)	.043
Sex: female	-.434	.648 (.479, .875)	.005
Diabetes: yes	.401	1.493 (1.159, 1.924)	.002
Baseline weight (kg)	.007	1.007 (1.002, 1.013)	.011
Diet extended: yes	.569	1.766 (1.139, 2.739)	.011
Kcals			
<800	-	-	-
800–1000	.144	1.155 (.578, 2.305)	.683
1000–1200	-.627	.534 (.257, 1.113)	.094
>1200	-1.099	.333 (.133, .832)	.019
Diet formulation			
Nonsolid food	-	-	-
Food	-.441	.643 (.421, .982)	.041
Meal replacements	.220	1.246 (.693, 2.240)	.461
Meal replacements + food	.283	1.327 (.856, 2.057)	.206
Duration			
1 wk	-	-	-
2 wk	.478	1.613 (.794, 3.277)	.186
3 wk	.825	2.282 (1.023, 5.086)	.044
4 wk	1.091	2.977 (1.283, 6.905)	.011
>5 wk	1.254	3.504 (1.331, 9.222)	.011
Random effect			
Variance (95% CI)	.036	(.003, .411)	.415

CI = confidence interval.

Discussion

This is the first multicenter study on a national scale to examine the outcomes of a range of LRDs utilized in clinical practice before bariatric surgery. Previous research has shown that a $\geq 5\%$ weight loss before bariatric surgery is shown to reduce liver volume by up to 23.0% [8,14]. Our findings suggest less than a third (30.6%) of patients undertaking an LRD before bariatric surgery have a $\geq 5\%$ weight loss. We also found that there is now greater variation in the formulation and energy prescription of LRDs utilized in UK clinical practice, compared with 2012 [18].

Variation in LRD interventions

The duration of LRDs utilized in today's clinical practice are akin to 2012 practices [18], whereby three quarters of patients (76.7%) in our study were prescribed a shorter duration diet (≤ 2 weeks), compared with 75% of bariatric centers in 2012. However, we report that the prescribed energy and formulation of LRDs has become more variable in today's practice. In 2012, all centers that provided data prescribed a low-energy diet (LED) of 800 to 1000 kcal/d and the most common formulation of LRD was normal consistency food (59%). In our study, the most common formulation of LRD was liquid consistency food (68.1%), and there is now more variation in energy prescription. The heterogenous nature of LRD interventions within our study is not surprising, given that international clinical guidelines [20,21] do not specify recommendations on how LRDs should be delivered in practice.

04 Patient characteristics

Men characteristically have a higher body mass (kg) and greater fat free mass (%) than women [23,24], and therefore men have a higher resting energy expenditure (REE) [25]. A 16% greater weight loss has been reported among men compared with women when following a fixed LED of 810 kcal for 8 weeks [23]. None of the bariatric centers included in our study prescribed a lower-energy LRD for women compared with men, and this may explain our findings that women had a reduced odds of attaining a 5% weight loss, suggesting that women should be prescribed a lower-energy prescription compared with men.

Patients with T2D had greater odds of achieving a 5% weight loss during the LRD compared with those without diabetes. In a large retrospective cohort study from the US and Canada [26], patients achieving a $>5\%$ or $>10\%$ weight loss were also more likely to have T2D ($P \leq .001$). We acknowledge that we did not collect data on T2D medications or glycemic control in our study, and therefore further research is required to examine these findings, in particular whether diabetes pharmacotherapy, such as GLP-1 receptor agonists, may explain greater weight loss among patients with T2D in the LRD period.

LRD energy prescription

These findings support the use of energy restriction of <1200 kcal/d, either in the form of a LED (800–1200 kcal/d) or very low-energy diet (VLED) (<800 kcal/d). However, we would argue that in clinical practice, LED energy prescriptions may be the preferable recommendation for patients. In a parallel randomized trial of a 3-week VLED versus LED before bariatric surgery [8], both interventions significantly decreased hepatic volume (-15.6% , $P = .045$; -12.3% , $P = .045$, respectively) and, moreover, there was no difference in the reduction of hepatic volume between groups ($P = .409$). In addition, a significantly higher proportion of participants in the VLED group reported adverse events of dizziness and physical weakness ($P \leq .05$). Ketonuria measurements have also indicated that only 26% of patients were compliant with a VLED before bariatric surgery, suggesting difficulties with adherence at this level of energy restriction [27].

A LED may be favorable to minimize the transient increases in liver enzymes that have been reported during LRDs prior to bariatric surgery. In a randomized controlled trial of a 3-week VLED (800 kcal/day) versus LED (1200 kcal/day) LRD, after adjustment, there was a significant increase in ALT in the VLED group of 12.3 U/L ($P = .001$), but not in the LED group ($P = .108$). Although enzyme elevation is transient and is shown to normalize after a period of weight stability [28], a less restrictive LED may be favorable over a VLED, to minimize exacerbation of liver injury during the preparatory period before surgery.

LRD formulation

Patients following a normal consistency food LRD had reduced odds of attaining a 5% weight loss, compared with a liquid consistency food diet. It is proposed that liquid consistency food formulations of LRDs are more restricted and are more convenient to prepare than conventional food. Indeed, in a RCT of a liquid versus normal consistency food LRD [27], visceral fat was significantly lower at 2 weeks for a liquid (-20.6%) compared with the normal consistency food (-28%) LRD ($P = .041$).

However, during a liquid LRD formulation self-reported hunger was significantly higher among the liquid versus normal consistency food-based diet groups at 1 week ($P = .004$) and 2 weeks ($P \leq .0001$) [27]. Inhibitory control is impaired in adults with obesity [29] and hence solid or more viscous formulations of meal replacements, or a combined meal replacement + food formulation, may be preferable to manage hunger levels and increase compliance.

LRD duration

Compared with a 1-week LRD, an LRD of ≥ 3 weeks increases the odds of attaining 5% weight loss. Previous research has examined changes in liver volume during a

6-week VLED before bariatric surgery, with measurements obtained at 2, 4, and 6 weeks [30]. It was concluded that a 4-week duration is the ideal period for a LRD, since the liver volume reached a maximum reduction at 4 weeks, suggesting decreasing compliance to the LRD between 4 and 6 weeks. However, no measurements were taken at the 3-week timepoint to distinguish where 3 or 4 weeks of LRD is an optimal duration. An LRD of ≥ 5 weeks duration may be unnecessary and could negatively impact on patient compliance [31], negating any potential benefit of an extended duration of LRD.

Strengths and limitations

The main strengths of this study are the large sample size across multiple centers and the generalizability of findings to international clinical practice, as our population was reflective of the international demographic characteristics of patients undergoing bariatric surgery [32]. Limitations of this study include the retrospective approach to data collection, which meant a small proportion of the eligible population (8.1%) were excluded from the analysis due to missing data; it was not feasible to obtain measurements of changes to liver volume or to obtain data on the macronutrient composition of the LRDs utilized.

The focus of our study was on the preoperative period only, hence we did not examine whether weight loss during LRDs influences postoperative outcomes. Although individual studies examining LRDs and postoperative complications show conflicting findings, ERAS Society Recommendations [11] concluded from the available literature that there is a moderate level of evidence that LRDs do reduce postoperative complications. However, owing to mortality event rates being so low following bariatric surgery it is difficult to ascertain whether preoperative weight loss during LRDs is associated with mortality risk [33].

A 5% weight loss is recommended to reduce liver steatosis in NAFLD [13], however there are limited studies within the bariatric surgery population [8,14] examining whether this is an optimal weight loss to significantly reduce liver volume during LRDs and whether this is indeed associated with a reduction in postoperative complications. Hence, measurements of changes in liver volume and postoperative data on a large sample of patients is required to confirm that a 5% weight loss is the appropriate recommendation within this population group.

Conclusion

There is a wide variation in the way LRDs are delivered in clinical practice, suggesting that a consensus on how LRDs should be delivered in clinical practice is needed. Our findings support that a liquid consistency food, meal

replacement or a combined meal replacement + normal consistency food formulation, containing 800 to 1200 kcal/d, for a duration of 3 to 4 weeks is the most effective LRD for 5% weight loss before bariatric surgery. Women may require a lower-energy LRD than men, and this should be examined by further research. Finally, given the wide variation in how LRDs were delivered, there is a need for further prospective, high-quality research to confirm our findings and determine more precisely which formulation of LRD is most effective before an evidence-based consensus on LRDs for clinical practice can be reached to standardize patient care.

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Supplementary materials

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