Abstract. Severe calorie restriction for treating the obese reduces serum triiodothyronine (T3) and energy expenditure, and may be counterproductive. In order to avoid severe calorie deficiency, we measured the individual minimum energy requirements (threshold, T) in 17 obese females and fed each on a sub-threshold diet, comprising the maximum number of calories commensurate with weight loss (T-200 cals). Mean T-200 was 1318 ± 96 cals, but the mean weight loss after 16 weeks on a sub-threshold diet (STD) was identical (17 kg) to that obtained by 22 age-matched female controls on a classical diet of 659 ± 59 cals, exactly half the intake. Weight loss on the classical diet was initially rapid but decelerated sharply after 8 weeks, while on the sub-threshold diet the rate of loss remained constant throughout.

In a second study, thyroid hormone measurements were performed three times weekly in 27 obese females during the 4 week period required to establish T. The mean weight loss was 4.02 ± 0.3 kg, but T3 levels varied minimally and very transiently. STD produces short-term results similar to those obtained by severe calorie deprivation, but is more acceptable to the patient. It appears not to provoke the fat-saving reflexes provoked by the classical, low-calorie diet.

Calorie restriction is accompanied by reduction in triiodothyronine (T3) (Suda et al. 1978; Grant et al. 1978) and resting metabolic rate (RMR) (Moore et al. 1980). These probably contribute to the adaptation in energy expenditure responsible for the progressive slowing, and in some cases arrest, of weight loss which occur with minimal calorie diets. Indeed, Moore et al. (1980) showed that in semi-starvation those patients whose weight loss tended to plateau also achieved the lowest T3 and RMR values.

Grant et al. (1978) found that the fall in T3 in calorie-deprived patients was accompanied by prolongation in the half-life of thyroxine (T4), suggesting to them that the primary response to semi-starvation is a fall in the rate of peripheral metabolism of T4.

It has also been shown that the administration of physiological doses of T3 to patients on a severely restricted calorie diet will prevent the fall in RMR and permit weight loss to continue (Carter et al. 1975; Moore et al. 1980) by maintaining the catabolic rate. There is thus circumstantial evidence to suggest that in low-calorie states the deficiency in carbohydrate leads in many instances to reduced peripheral deiodination of T4 to T3, reduced RMR and reduced catabolism. The causal links between these phenomena require confirmation, but their relationship to dietary resistance seems clear.

Thyroid hormone treatment, however, is potentially dangerous. The object of this study was to compare the effectiveness of diets containing the maximum number of calories commensurate with weight loss (sub-threshold diets, STD) with conventional low-calorie diets, and to study their effect on thyroid hormones.
Materials and Methods

Sub-threshold dieting (STD)
The principle – to supply the maximum number of calories consistent with weight loss – was established empirically by one of us, Y.S. The patient is fed freely for 48 h and then placed on an (arbitrary) 400-cals intake. Each time the patient loses 100 g or more in weight within a 24 h period, he is 'rewarded' with a 100-calorie increase in his diet. After a variable period, usually about 3 weeks, the patient reaches a plateau where he neither gains nor loses further weight. The calorie intake on this plateau (the minimum maintenance requirement) is referred to as the threshold (T), which in our experience may vary from 900 cals/day to 2800 cals/day. Four days of stable weight are required to confirm that the threshold has been reached, and the sub-threshold diet on which the patient is then placed is simply T-200 calories, whatever the value of T. Thus STD standardises the calorie deficit (relative to need) while a classical weight-reducing diet standardises the calorie intake (irrespective of need).

Two separate studies were undertaken, the first to compare the effectiveness of STD with that of conventional dieting, the second to explore the behaviour of circulating thyroid hormone levels in obese patients on STD.

Study 1. The mean weight loss in 17 obese female patients (mean age 39.4 ± 2.8 years) on a sub-threshold diet was compared over 16 weeks with the corresponding loss in 22 obese female controls (mean age 40 ± 5.7 years) treated by classical calorie restriction (less than 1000 cals). The test patients were 40.67 ± 4.8 kg in excess of ideal weight at the start, and those on the conventional diet 33.10 ± 3.5 kg.

All subjects were hospitalised in a dietary centre for the first 4 weeks, during which time thresholds for the 17 patients were established and classical diets for the controls started. The diets were self-administered at home during the subsequent 3 months with out-patient surveillance once a month. Considerable encouragement to maintain the diets was given to all subjects at each visit, and their calorie consumption was checked against what had been prescribed initially. While it is always difficult to judge compliance at home, we were rigorous in eliminating any patient or control who failed, even if only once, to attend for review, whatever the excuse. Thus 40 subjects had originally embarked on the threshold regimen and 33 on the control diet, but only 17 and 22, respectively, were retained for analysis.

Study 2. Serum levels of triiodothyronine (T3), thyroxine (T4), reverse triiodothyronine (rT3), thyrotrophin (TSH) and thyroxine binding globulin (TBG) were measured by radioimmunoassay three times weekly for 2 weeks and twice weekly for a further 2 weeks in 27 obese patients (three males, 24 females, mean age 38.6 ± 4.2 years; mean weight 90.18 ± 3.77 kg) before, during and after establishment of T, in order to find out whether STD was associated with the same perturbations in thyroid hormones as have previously been demonstrated for low-calorie diets (Grant et al. 1978). Patients were weighed in their nightclothes at between 7 and 8 a.m., after emptying of the bladder but before breakfast, by a single observer using a lever balance accurate to 100 g.

Ideal weight was derived from the Standard Life Assurance tables. The statistical comparisons of means were made with Student's paired or unpaired t-test as appropriate. All means are accompanied by the SEM.

Results

Study 1
The mean T in the STD patients was 1541 ± 92 cals, and their subsequent mean dietary intake 1318 ± 96 cals/day (T-200 cals). These patients

![Fig. 1](https://via.placeholder.com/150)

Progression of weight loss in 17 obese female patients on a sub-threshold diet (STD, interrupted line) compared with that of 22 obese female controls on a restricted calorie diet (659 ± 57 cals/day) (continuous line), expressed as the per cent of the remaining excess weight lost each month. T = mean achievement of threshold in STD group; * denotes statistically significant change in relation to previous month (P < 0.05).
took 22 ± 1.4 days to establish T and lost 17.26 ± 1.47 kg during the entire 16 weeks. The calorie intake of the controls on leaving hospital was 659 ± 57 cals and their weight loss overall was 17.75 ± 1.70 kg, identical to that of the STD patients. Fig. 1 shows the pattern of weight loss in patients and controls in terms of the per cent remaining excess weight lost each month. Weight loss accelerated rapidly during the early weeks in controls, but decelerated sharply thereafter. They lost an average of only 2.48 kg during month 4, compared with 6.29 kg during month 2. Weight loss in the STD patients on a standard 200 cals deficit was more regular, with no major fluctuations in the rate of weight loss nor, seemingly, a tendency to plateau.

Table 1.
Mean thyroid hormone and thyroxine-binding globulin (TBG) levels in 27 obese patients before, during and after establishment of their dietary threshold (T).

<table>
<thead>
<tr>
<th></th>
<th>Week 1</th>
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<th>Week 2</th>
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<tr>
<td>T&lt;sub&gt;3&lt;/sub&gt; (nmol/l)</td>
<td>1.73</td>
<td>1.62</td>
<td>1.50</td>
<td>1.56</td>
<td>1.53</td>
<td>1.50</td>
<td>1.58</td>
<td>1.56</td>
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<tr>
<td>T&lt;sub&gt;4&lt;/sub&gt; (µmol/l)</td>
<td>136</td>
<td>135</td>
<td>138</td>
<td>136</td>
<td>125</td>
<td>126</td>
<td>131</td>
<td>134</td>
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<tr>
<td>T&lt;sub&gt;3&lt;/sub&gt;/T&lt;sub&gt;4&lt;/sub&gt; x 1000</td>
<td>12.5</td>
<td>12.0</td>
<td>11.0*</td>
<td>11.5*</td>
<td>12.2</td>
<td>12.0</td>
<td>12.2</td>
<td>11.7</td>
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<td>rT&lt;sub&gt;3&lt;/sub&gt; (nmol/l)</td>
<td>0.26</td>
<td>0.31*</td>
<td>0.32*</td>
<td>0.32*</td>
<td>0.32*</td>
<td>0.32*</td>
<td>0.32*</td>
<td>0.29*</td>
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<tr>
<td>TBG (µmol/l)</td>
<td>3.45</td>
<td>3.36</td>
<td>3.33</td>
<td>3.30</td>
<td>3.22</td>
<td>3.25</td>
<td>3.40</td>
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<td>T&lt;sub&gt;4&lt;/sub&gt;/TBG</td>
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<td>T&lt;sub&gt;3&lt;/sub&gt;/TBG x 10</td>
<td>5.36</td>
<td>5.16</td>
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<td>4.85</td>
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<tr>
<td>TSH mU/l</td>
<td>2.1</td>
<td>1.9</td>
<td>2.0</td>
<td>1.8</td>
<td>1.9</td>
<td>1.9</td>
<td>2.2</td>
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* Denotes a statistically significant change of P < 0.05 in relation to the first day.
Fig. 2 shows the inverse relationship between weight loss and dietary gain during establishment of T, which in this group averaged 1456 ± 84 cals/day. Thyroid hormone perturbations during these 4 weeks were minimal and transitory (Table 1). All parameters returned to baseline within 2 weeks, well before T was established. The level of T3 in particular (corrected for slight variations in TBG) showed no signs of a long-term fall, returning to baseline within 7 days. Reverse T3 is known to be highly sensitive to reductions in calorie intake, but the rise in these patients was minimal and transient. Thus, STD was not associated with the perturbations in thyroid hormone levels seen in classical dieting.

Discussion

The first study suggests that sub-threshold dieting (STD) is as effective in producing weight loss as the classical low-calorie method, and the second that serum T3, known to be markedly reduced in calorie-deprived states (Moore et al. 1980), is not perturbed in patients on a sub-threshold diet. Sub-threshold dieting therefore merits serious consideration, particularly as a regimen averaging 1250 cals is likely, a priori, to be nutritionally better balanced and psychologically better tolerated than one of half that content.

The fundamental difference between STD and low-calorie dieting lies in control of the calorie deficit. The calorie intake in STD is the maximum consistent with weight loss and is tailored to fall just short of the individual's energy expenditure. In our experience, the dietary threshold has ranged from 900 to 2800 cals. The classical low-calorie diet (less than 1000 cals) does not take account of this wide individual variation in T. The calorie content may thus be too great for some, while grossly deficient for others. Investigation of low-calorie diets has shown that large calorie deficits are met with a sustained fall in serum T3 of between 20 and 30% and rise in the metabolically inactive rT3, together with metabolic adaptation sometimes sufficient to arrest weight loss entirely (Moore et al. 1980). STD, in contrast, is not associated with this fall in T3 and the pattern of weight loss, during the first 12 to 16 weeks at least, does not show the plateau effect characteristic of adaptation. We are currently engaged in longer term comparisons to establish whether the benefits of STD are definitive.

Acknowledgment

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References


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