There are hardly any studies concerning thyroid functioning in obese children. Experiments on animals have shown a correlation between thyroid hormones and changes in weight. Studies on thyroid hormones in obese adults are inconsistent. There has been discussion as to whether leptin influences the production of thyroid hormones. Long term changes in thyroid hormones caused by a reduction in weight have not been studied in depth.

We therefore analysed thyroid stimulating hormone (TSH), triiodothyronine (T3), thyroxine (T4), and leptin in obese children before and after weight reduction based on normal energy diet, compared to healthy children of normal weight.

**MATERIALS AND METHODS**

We examined all children with non-syndromal obesity, defined by a body mass index (BMI) above the 97th centile who attended the intervention programme “Obeldicks” for obese children between 1999 and 2000. Reference data from Rolland-Cachera and colleagues were used, as proposed by the European childhood obesity group.

Thyroid hormone parameters (T3, T4, TSH), leptin, degree of overweight as a z score from the BMI according to the LMS method, which includes an age dependent factor controlling for variation and skewness of the BMI distribution, as well as age, sex, and stage of puberty according to Tanner were established. After one year the same parameters were determined for all those taking part in the intervention programme “Obeldicks”. These data were compared to thyroid function (T3, T4, TSH) of 107 non-obese healthy children with short stature and a BMI below the 90th centile.

TSH, total T3, and total T4 were determined by solid phase chemiluminescence—immunoassays (Immulite). The norm values for the respective age range were between 0.2–0.4 and 5.4–6.1 mIU/l for TSH, between 0.6 and 3.1–3.5 nmol/l for T3, and between 46–54 and 160–178 nmol/l for T4. Leptin was measured with an enzyme immunoassay (DRG). The intraassay coefficients of variation were 3.9% for TSH, 5.4% for T3, and 6.3% for T4. The interassay coefficients of variation were 8.0% for TSH, 7.1% for T3, and 6.7% for T4.

In all children, autoimmune thyroiditis was excluded by measuring antimicrosomal and thyroglobulin antibodies for TSH concentrations above 5 mU/l or above the twofold standard deviation based on the 107 normal weight children (see table 1) and for goitre. Children with endocrine or metabolic disorders were excluded from the study. Smokers and children taking any medication including oral contraceptives were also excluded. Growth hormone deficiency was excluded in all children with short stature.

The reduction in weight was achieved through the intervention programme “Obeldicks” for obese children based on a one year therapy with behavioural components, physical exercise, and normal energy diet.

Statistical analysis was performed by the Statistical Package for Social Sciences (SPSS). Stastically significant differences were tested by the non-parametric Mann-Whitney U test, paired observation by the non-parametric Wilcoxon test, correlations by the Spearman rank test, and dependent variables by partial correlation.

**RESULTS**

A total of 119 obese children presented for participation in the intervention programme “Obeldicks”. One child was excluded because of autoimmune thyroiditis. In the last three months before schooling no child had had a change in weight.

Obese children showed significantly higher serum concentrations of TSH, T3, and T4 than the non-obese children (see table 1). The group of obese children did not differ with respect to age, sex, or stage of puberty from the group of non-obese children.

Thyroid serum concentrations were above the

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**References**

1. Little is known about changes in thyroid function in obese children. An influence of leptin on thyroid hormone synthesis has been proposed.

2. To examine thyroid function and leptin concentrations in obese children.

3. Triiodothyronine (T3), thyroxine (T4), thyroid stimulating hormone (TSH), and leptin were measured in 118 obese children (aged 4.5–16 years); thyroid function was also determined in 107 healthy children of normal weight. T3, T4, and TSH were analysed in 55 obese children who had achieved weight reduction and in 13 obese children who had not achieved weight reduction after one year based on normal energy diet.

4. Results: TSH, T3, and T4 were significantly higher in obese children compared to those of normal weight. Twelve per cent of the obese children had TSH, 15% had T3, and 11% had T4 concentrations above the twofold standard deviation of normal weight children. The degree of overweight correlated with T3, T4, and TSH. Thyroid hormones did not correlate significantly with leptin. A reduction in overweight showed a significant decrease in T3, T4, and leptin serum concentrations, but there was no significant change in TSH.

5. Peripheral thyroid hormones (T3, T4) and TSH are moderately increased in obese children; weight reduction leads to a long term decrease in the peripheral thyroid hormones but not in TSH. There is no necessity to treat the increased serum TSH.

**Abbreviations:**
BMI, body mass index; MAK, microsomal autoantibodies; rT3, reverse triiodothyronine; T3, triiodothyronine; T4, thyroxine; TAK, thyroid activating autoantibodies; TRAK, thyroglobulin autoantibodies; TSH, thyroid stimulating hormone.
two-fold standard deviation based on the 107 normal weight children in 14 (12%) of the 118 obese children, T3 serum concentrations in 18 (15%), and T4 serum concentrations in 13 (11%) obese children. There was no correlation between TSH, T3, and T4 serum concentrations, and age, sex, or stage of puberty. No child had a goitre. The thyroid hormones correlated with the degree of overweight (z score BMI; see table 2). The thyroid hormones did not correlate significantly with leptin (T3; \( r = 0.07, p = 0.46 \); T4; \( r = -0.05, p = 0.60 \); TSH; \( r = 0.16, p = 0.11 \)). As both leptin and the thyroid hormones correlated with the degree of overweight, partial correlation adjusted to the degree of overweight was used.

Table 1 Age, gender, degree of overweight (z score BMI), and serum TSH, T3, and T4 in obese and non-obese children

<table>
<thead>
<tr>
<th></th>
<th>Non-obese</th>
<th>Obese</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>107</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>43% girls</td>
<td>47% girls</td>
<td>0.586</td>
</tr>
<tr>
<td>Age (y)</td>
<td>11.3 (4.0–16.0)</td>
<td>11.5 (4.5–16.0)</td>
<td>0.938</td>
</tr>
<tr>
<td>z score BMI</td>
<td>−0.5 (−1.8 to +1.3)</td>
<td>+3.2 (+1.9 to +4.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TSH (mIU/l)</td>
<td>2.0 (0.2–4.8)</td>
<td>2.4 (0.8–10.5)</td>
<td>0.001</td>
</tr>
<tr>
<td>T3 (nmol/l)</td>
<td>2.2 (1.4–3.4)</td>
<td>2.5 (1.5–6.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>T4 (nmol/l)</td>
<td>103 (55–184)</td>
<td>116 (24–172)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 2 Correlation of thyroid hormones to degree of overweight (z score BMI) in 118 obese children

<table>
<thead>
<tr>
<th></th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSH</td>
<td>0.21</td>
<td>0.0002</td>
</tr>
<tr>
<td>T3</td>
<td>0.27</td>
<td>0.0001</td>
</tr>
<tr>
<td>T4</td>
<td>0.25</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

Table 3 Degree of overweight (z score BMI), thyroid hormones, and leptin before and one year later after weight loss in 55 obese children

<table>
<thead>
<tr>
<th></th>
<th>Before weight loss</th>
<th>After weight loss</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>z score BMI</td>
<td>+3.1 (+1.9 to +4.1)</td>
<td>+2.4 (+0.8 to +3.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>TSH (mIU/l)</td>
<td>2.34 (0.8–7.8)</td>
<td>2.24 (0.98–6.33)</td>
<td>0.491</td>
</tr>
<tr>
<td>T3 (nmol/l)</td>
<td>2.30 (1.69–6.14)</td>
<td>2.15 (1.31–3.69)</td>
<td>0.001</td>
</tr>
<tr>
<td>T4 (nmol/l)</td>
<td>114 (73–157)</td>
<td>101 (24–137)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Leptin (ng/ml)</td>
<td>20.8 (2.2–124.0)</td>
<td>14.8 (1.0–54.0)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 4 Degree of overweight (z score BMI), thyroid hormones, and leptin before and one year later in 13 obese children without weight loss

<table>
<thead>
<tr>
<th></th>
<th>Before weight loss</th>
<th>After unsuccessful weight loss</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>z score BMI</td>
<td>+2.7 (+2.2 to +3.7)</td>
<td>+2.9 (+2.2 to +4.0)</td>
<td>0.166</td>
</tr>
<tr>
<td>TSH (mIU/l)</td>
<td>2.15 (1.09–5.06)</td>
<td>2.01 (0.67–4.05)</td>
<td>0.115</td>
</tr>
<tr>
<td>T3 (nmol/l)</td>
<td>2.00 (1.54–3.38)</td>
<td>2.46 (1.31–3.23)</td>
<td>0.914</td>
</tr>
<tr>
<td>T4 (nmol/l)</td>
<td>110 (83–145)</td>
<td>101 (64–132)</td>
<td>0.055</td>
</tr>
<tr>
<td>Leptin (ng/ml)</td>
<td>27.0 (2.0–93.0)</td>
<td>25.3 (7.0–54.0)</td>
<td>0.167</td>
</tr>
</tbody>
</table>

DISCUSSION

In obese children, serum concentrations of thyroid hormones (TSH, T3, T4) were on average above those of the children of normal weight, and decreased (T3, T4) after weight loss from a normal energy diet; this points to a reversible increase of thyroid hormones in obesity. These changes of TSH and T3 are not caused by other influencing factors, as without weight loss in a collective of obese children, serum concentrations of thyroid hormones, and leptin in 118 obese children were significantly lower than in the non-obese children (Table 1). The decrease of TSH and T3 was not caused by differences in age, sex, or stage of puberty, as the children who lost weight after a normal energy diet were similar to those who did not lose weight (Table 3). The thyroid hormones of the 13 children who did not lose weight successfully after a year did not change significantly compared to their initial values (Table 4).
children of the same age, gender, and degree of overweight, there was no change in thyroid status over the same time period.

As both TSH and the peripheral thyroid hormones (T3 and T4) are increased in obesity, there is no necessity for treatment of the increased TSH serum concentrations, as T3 is the biologically active thyroid hormone and is crucial for metabolism. A moderate rise in total and free T3 and TSH serum concentrations of obese children, as in our group, has been shown in a number of other studies. The cause of the increased thyroid hormone concentrations in obesity is unclear. In a study in children, the increase in TSH serum concentrations was not accounted for by iodine deficiency or autoimmune thyroiditis. Increased thyroid hormone concentrations could point to hormone resistance, similar to insulin resistance in obesity. In support of this theory is the fact that in obesity T3 receptors are decreased, and the negative feedback between TSH and the peripheral thyroid hormones (T3, T4) is decreased, as both TSH and the peripheral thyroid hormones are increased in obesity. The patients with the highest serum TSH concentrations had high serum T3 concentrations. To determine whether pituitary responsiveness is altered in obese children, a TRH test would be useful.

As the thyroid hormones—especially T3—regulate both the resting metabolic rate and thermogenesis and lead to lipolysis, changes in thyroid hormones could also point to an adaptation process in obesity. When the peripheral thyroid hormones decrease after a reduction of overweight, we can also expect a reduction in resting metabolic rate and consequently a reduction in energy expenditure. This decrease in energy expenditure as a result of weight loss has been shown in several studies in children.

Production of TSH is also regulated by transmitters and hormones which regulate body weight and satiation, such as neuropeptide Y, anorexigenic hormones, and the agouti related peptide innervating hypothalamic TRH neurons. These transmitters are also influenced by leptin, which correlates with the degree of adipose tissue. Some studies have described a correlation between leptin and TSH; indeed leptin has even been considered the mediator responsible for the increase in the production of TSH. However, in our study as well as in one further study, no significant correlation between TSH and leptin could be identified, although in our analysis we used partial correlation results. As TSH is the bio-logically active thyroid hormone and is crucial for metabolism, it is doubtful that leptin is important as a mediator in thyroid changes. There is still a need for further research into the changes in thyroid hormones (especially TRH test, TSH, free T3, and T4) in obesity and weight loss.

**REFERENCES**


Blood pressure after repair of coarctation

Adults who have had coarctation of the aorta repaired in childhood are at increased risk of hypertension compared with the general population. In most published follow up series the age at coarctation repair was quite high and it is known that late repair increases the risk of hypertension. Now data have been reported from a cohort in Newcastle upon Tyne (JJ O’Sullivan and colleagues. Heart 2002;88:163–6) whose coarctations were repaired early.

From a cohort of 166 children born between 1983 and 1992 with coarctation of the aorta 119 survivors were followed up with full data. Mean age at repair was 0.2 years and at follow up 12 years. All were thought to have had a satisfactory repair. At follow up echocardiography 70 children were considered to have no arch obstruction and 49 mild obstruction. Of those with no arch obstruction 15 (21%) had a high (>95th centile) casual systolic blood pressure (mean of three readings) and 13 (19%) had a high mean 24 hour systolic blood pressure. For those with mild arch obstruction the corresponding figures were 19/49 (39%) and 23/49 (49%). High systolic blood pressure on casual readings was 66% sensitive and 88% specific for high mean 24 hour systolic blood pressure.

Systolic hypertension is common in later childhood after early repair of coarctation of the aorta even in the absence of significant residual arch obstruction. There is uncertainty about the need for treatment of this hypertension. Its cause also seems uncertain.