

Thyroid-Stimulating Hormone, Degree of Obesity, and Metabolic Risk Markers in a Cohort of Swedish Children with Obesity

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Keywords

Thyroid-stimulating hormone · Triiodothyronine · Thyroxine · Childhood obesity · Body mass index standard deviation scores

Abstract

Background/Aims: Thyroid-stimulating hormone (TSH) is affected in obesity and might influence metabolic risk. It is unclear what mechanisms cause elevated TSH in obesity. We aimed to investigate TSH status within the normal range and the association of TSH with degree of obesity and metabolic parameters in children with obesity. **Methods:** A total of 3,459 children, aged 3.0–17.9 years, were identified in the Swedish Childhood Obesity Treatment Registry, BORIS. Age, gender, TSH, free triiodothyronine (fT3), free thyroxine (fT4), body mass index standard deviation scores (BMI SDS), as well as variables of lipid and glucose metabolism were examined. **Results:** Children with high-normal TSH (>3.0 mU/L) (28.8%) had higher BMI SDS compared to children with low-normal TSH (<3.0 mU/L) ($p < 0.001$). Multivariable regression analysis adjusted for age and gender showed that TSH levels were associated with BMI SDS (β : 0.21, 95% CI: 0.14–0.28, $p < 0.001$). Associations of thyroid hormones with markers of lip-

id and glucose metabolism were observed, where TSH was associated with fasting insulin, HOMA (homeostatic model assessment of insulin resistance), total cholesterol, and triglycerides. **Conclusions:** A positive association between TSH levels and BMI SDS was seen in children with obesity. Associations of TSH and free thyroid hormones with glucose metabolism indicated that TSH might be one of several factors acting to determine body weight and obesity co-morbidities, although the underlying mechanism remains unclear.

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Introduction

Thyroid-stimulating hormone (TSH) and body composition are closely related. TSH both directly [1–3], and indirectly via thyroid hormones [4], is involved in the regulation of basal metabolism and thermogenesis and thereby also in glucose and lipid metabolism [4–6]. In adults with obesity, TSH has frequently been reported to be elevated, but conflicting data with unaltered TSH and thyroid hormones have also been reported [7, 8]. In adults, a positive correlation has been reported between weight gain during 5 years and a progressive increase in

TSH level. Even slightly elevated TSH levels might be involved in the occurrence of obesity [9], but the cause of the higher TSH concentrations in obesity and the underlying mechanisms are unclear [10, 11].

It is well known that total and resting energy expenditure are positively associated with free triiodothyronine (fT3) levels [12], and it has been suggested that an increase in TSH, and secondarily in fT3, in obesity is an attempt to increase resting energy expenditure and inhibit the conversion of accumulated energy into fat [13]. In other words, an increase in TSH has been suggested as an adaptation to weight gain [14]. Studies investigating associations of free thyroxine (fT4) with metabolic risk have been limited in size, but it has been demonstrated in a population-based cohort that low fT4 levels among euthyroid subjects are associated with hyperlipidemia and insulin resistance [15].

Studies in children with obesity have reported an increased prevalence of elevated TSH [16, 17], but a lack of association has also been described [18, 19]. Increased levels of TSH have been reported to be associated with slightly elevated or normal fT4 and/or fT3 in the absence of overt thyroid dysfunction [10, 16].

Elevated TSH within the normal range has previously been shown to be associated with metabolic risk factors in obese children [19, 20] as well as in youths in the general population [21]. In some studies, weight loss has been reported to normalize TSH levels as well as metabolic parameters of glucose metabolism and lipid profile [22, 23], whereas 1 study did not find an association of TSH with lipid parameters even though TSH was reduced after weight loss [24]. However, despite a large number of studies, it is still unclear whether high TSH levels are compensatory to maintain normal thyroid hormone levels, and it is also unclear whether TSH is associated with metabolic disturbances in children with obesity since previously published research are inconsistent [25].

In order to clarify these issues we aimed to investigate TSH status and its association with the degree of obesity in children. We hypothesize that TSH levels are increased within the normal range to maintain normal thyroid hormone levels. Second, we aimed to investigate whether TSH and thyroid hormones within the normal range are associated with metabolic risk markers – fasting insulin (f-insulin), fasting glucose (f-glucose), HOMA (homeostatic model assessment of insulin resistance), triglycerides, total cholesterol, low-density lipoprotein (LDL) cholesterol, and high-density lipoprotein (HDL) cholesterol – in obese children, and we hypothesize that a high-normal TSH is accompanied with a more deranged metabolic profile.

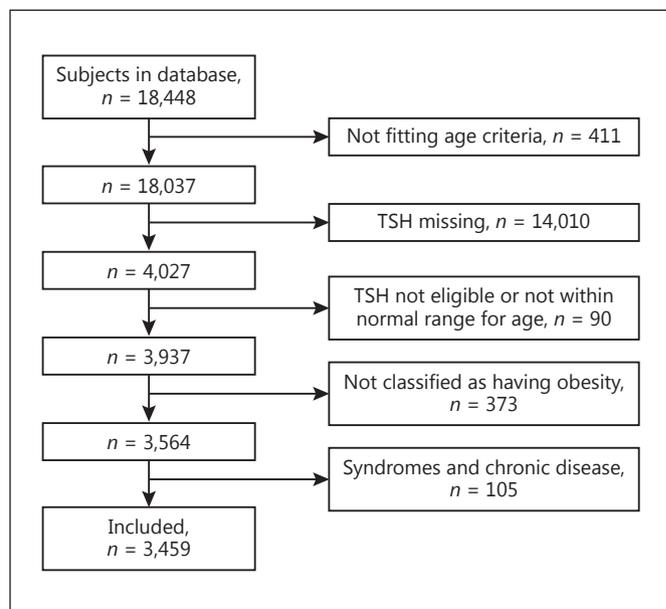


Fig. 1. Age criteria: 3–17.9 years. Thyroid-stimulating hormone reference ranges: age 3–6.9 years, 0.7–6.0 mU/L; age 7–11.9 years, 0.6–4.8 mU/L; and age 12–17.9 years, 0.5–4.3 mU/L (reference intervals for children and adults, Elecsys Thyroid Tests Elecsys 2010 system; Roche Diagnostics 2009). Obesity was defined according to the International Obesity Task Force (IOTF) BMI cutoffs [26].

Materials and Methods

The design was a retrospective cohort study consisting of children and adolescents registered in the Swedish Childhood Obesity Treatment Registry, BORIS (www.e-boris.se). The children were enrolled in obesity treatment from pediatric clinics all over Sweden between August 1995 and June 2016. Inclusion criteria were children classified as obese according to Cole and Lobstein [26] with records of TSH levels. Exclusion criteria were diagnosed thyroid disease (subclinical and overt hypo- and hyperthyroidism, Graves' disease, Hashimoto's thyroiditis, and thyroid hormone treatment in general) and the presence of hypothalamic or pituitary disturbances, central nervous system damage, or syndromes (Prader-Willi syndrome, Down syndrome, and Laurence-Moon-Bardet-Biedl syndrome) and other chronic diseases (Fig. 1). After exclusion a total of 3,459 children, aged 3.0–17.9 years, were identified within each age-specific normal TSH range. Ethical permission for data collection in BORIS was obtained by the regional committee of ethics in Stockholm (2014/381-31/5).

Procedure

All children had undergone anthropometric measurements by trained personnel. Body mass index (BMI) was calculated as weight in kilograms divided by height in square meters (kg/m^2), and international age- and gender-adjusted BMI standard deviation scores (BMI SDS) were used [26]. Fasting blood samples were obtained after an overnight fast, and routine biochemical analysis was performed at accredited hospital laboratories.

Table 1. Anthropometric and biochemical parameters in groups with moderate and severe obesity, and in low-normal and high-normal TSH groups

	All	Per group, <i>n</i>	Moderate obesity	Severe obesity	Per group, <i>n</i>	Low-normal TSH	High-normal TSH
Age, years	11.5±3.44	1,682/1,777	11.5±3.08	11.5±3.76	2,463/996	11.7±3.43	11.1±3.45**
Male/female, %	51/49	1,682/1,777	48/52	49/51	2,463/996	48/52	49/51
BMI SDS	2.94±0.46	1,682/1,777	2.58±0.18	3.29±0.36**	2,463/996	2.92±0.45	3.00±0.48**
Tanner stage	2.80±1.74	618/968	2.76±1.69	2.82±1.78	1,120/466	2.91±1.73	2.52±1.71**
TSH, mU/L	2.47±0.92	1,682/1,777	2.36±0.89	2.57±0.93**	2,463/996	1.99±0.54	3.64±0.53**
fT3, pmol/L	6.11±1.06	344/743	6.19±1.02	6.07±1.07	802/285	6.09±1.11	6.16±0.91
fT4, pmol/L	14.0±2.73	1,330/1,584	14.04±2.75	13.96±2.72	2,063/851	13.98±2.73	14.04±2.74
TSH/fT4 ratio ^a	0.17 (0.02–3.46)	1,330/1,584	0.16 (0.02–2.0)	0.18 (0.04–3.5)**	2,063/851	0.14 (0.02–2.0)	0.26 (0.15–3.5)**
Fasting insulin ^a , mU/L	12.0 (2.0–50.26)	275/591	10.7 (2.1–50.0)	13.0 (2.0–50.3)**	1,523/628	11.8 (2.0–50.3)	13.0 (2.2–50.0)
fasting glucose ^a , mmol/L	5.22 (2.5–12.6)	293/627	5.20 (3.2–12.6)	5.20 (2.50–10.9)*	2,195/873	5.20 (2.5–12.6)	5.20 (3.4–10.4)
HOMA ^a	2.72 (0.4–22.8)	257/559	2.39 (0.5–15.4)	2.95 (0.4–22.8)**	1,448/586	2.64 (0.4–22.8)	2.88 (0.4–12.6)*
Total cholesterol, mmol/L	4.26±0.78	1,491/1,643	4.26±0.80	4.25±0.78	2,224/910	4.23±0.79	4.31±0.78*
Triglycerides ^a , mmol/L	1.0 (0.3–4.96)	314/705	0.90 (0.3–4.75)	1.08 (0.3–4.96)**	2,284/926	0.95 (0.30–4.96)	1.00 (0.3–4.9)**
LDL cholesterol, mmol/L	2.66±0.72	1,463/1,492	2.64±0.71	2.69±0.72*	2,100/855	2.65±0.72	2.68±0.71
HDL cholesterol, mmol/L	1.21±0.30	1,479/1,492	1.25±0.30	1.17±0.29**	2,114/857	1.20±0.30	1.22±0.30

Data are presented as mean ± SD or median (min–max) for parametric and nonparametric variables, respectively. TSH, thyroid-stimulating hormone; BMI SDS, body mass index standard deviation scores; fT3, free triiodothyronine; fT4, free thyroxine; HOMA, homeostatic model assessment of insulin resistance. ^a Mann-Whitney U Test. * $p < 0.05$, ** $p < 0.001$.

Outcome Measurements

TSH, thyroid hormones fT3 and fT4, f-insulin, f-glucose, and fasting lipid profiles (including total cholesterol, triglycerides, and LDL and HDL cholesterol) were extracted from BORIS. As the samples were collected from all over Sweden, the methods for analyses may have differed. However, all routine analyses were performed by certified laboratories. Age-specific reference intervals used for TSH, fT3, and fT4 are as follows: age 1–6 years: TSH 0.7–6.0 mU/L, fT3 3.7–8.5 pmol/L, and fT4 12–23 pmol/L; age 7–11 years: TSH 0.6–4.8 mU/L, fT3 3.9–8.0 pmol/L, and fT4 13–22 pmol/L; age 12–18 years: TSH 0.5–4.3 mU/L, fT3 3.9–7.7 pmol/L, and fT4 13–21 pmol/L (reference intervals for children and adults, Elecsys Thyroid Tests Elecsys 2010 system; Roche Diagnostics 2009). The homeostatic model assessment of insulin resistance (HOMA) was calculated to obtain a measure of insulin sensitivity: (f-glucose mmol/L × f-insulin mIU/L)/22.5).

We used a cutoff of 3.0 mU/L to categorize individuals as having low- or high-normal TSH within the normal range for age. The TSH/fT4 ratio was calculated to investigate the relationship between TSH and fT4. To define the degree of obesity the International Obesity Task Force (IOTF) BMI cutoffs were used, where age- and sex-adjusted BMI cutoffs corresponding to BMI 30 and 35 are defined as obesity and severe obesity, respectively [26]. In the multivariable linear regression analysis the subjects were stratified by age according to age-specific normal intervals for TSH and thyroid hormones (3–6.9, 7–11.9, and 12–17.9 years of age). We also investigated the cohort divided by gender and stage of puberty assessed by Tanner stage as prepuberty, early puberty,

and puberty (Tanner stages 1 and 2 as prepuberty, 3 as early puberty, and 4 and 5 as puberty were documented [27]). Children without documented pubertal stage were stratified as follows: <7 years as Tanner stage 1 and adolescents >15.9 years as Tanner stage 5.

Statistical Analysis

Data were processed and analyzed using the statistical software IBM SPSS version 23. All data were controlled for normal distribution by inspection of histograms. Normally distributed data were presented as mean ± SD, and nonparametric data were presented as median (min–max). Between-group comparisons were performed using independent *t* tests or Mann-Whitney U and Kruskal-Wallis tests according to a normal or a nonparametric distribution of the tested variable. Multivariable linear regression models were calculated to investigate the impact of BMI SDS (independent variable) on TSH and thyroid hormones (dependent variables) after controlling for age and gender. To study how TSH and thyroid hormones were associated with metabolic parameters, multivariable regression analyses adjusted for age, gender, and BMI SDS were performed with TSH, fT3, and fT4, respectively (independent variables) on parameters of lipid and glucose metabolism (dependent variables). To further evaluate the independent contribution of TSH and fT3, we simultaneously included TSH and fT3 as covariates in the regression model. All tests for significance were 2-sided, and *p* values <0.05 were considered statistically significant.

Table 2. Multivariable regression analysis of the impact of BMI SDS (independent variable) on TSH, fT3, and fT4 respectively (dependent variables) controlling for age and gender, and multivariable regression analysis of the impact of TSH, fT3, or fT4 (independent variables) on variables of lipid and glucose metabolism (dependent variables), controlling for age, gender, and BMI SDS

	TSH (n = 3,459)	fT3 (n = 1,087)	fT4 (n = 2,914)
BMI SDS	0.21 (0.14 to 0.28)**	-0.09 (-0.22 to 0.04)	-0.01 (-0.22 to 0.21)
Fasting insulin, mU/L	0.77 (0.27 to 1.26)*	0.91(0.19 to 1.62)*	-0.14 (-0.31 to 0.04)
Fasting glucose, mmol/L	0.02 (-0.02 to 0.04)	0.08 (0.04 to 0.12)**	-0.01 (-0.02 to 0.001)
HOMA	0.19 (0.06 to 0.31)*	0.28 (0.10 to 0.46)*	-0.02 (-0.70.02)
Total cholesterol, mmol/L	0.05 (0.02 to 0.08)*	-0.07 (-0.12 to -0.02)*	-0.02 (-0.03 to -0.01)**
Triglycerides, mmol/L	0.06 (0.04 to 0.09)**	0.03 (to 0.01 to 0.07)	-0.02 (-0.03 to -0.01)**
LDL cholesterol, mmol/L	0.01 (-0.02 to 0.04)	-0.04 (-0.10 to 0.01)	-0.02 (-0.03 to -0.01)*
HDL cholesterol, mmol/L	0.01 (-0.000 to 0.02)	-0.01 (-0.03 to 0.01)	0.01 (0.004 to 0.01)**

Data are presented as β coefficient (95% CI). TSH, thyroid-stimulating hormone; BMI SDS, body mass index standard deviation scores; fT3, free triiodothyronine; fT4, free thyroxine; HOMA, homeostatic model assessment of insulin resistance. * $p < 0.05$, ** $p < 0.001$.

Results

In total, 3,459 individuals (49% female) with a mean age of 11.5 ± 3.44 years were included; 51.3% ($n = 1,777$) were severely obese. The prevalence of high-normal TSH levels (≥ 3.0 mU/L) was 28.8% ($n = 996$) in our cohort of obese children. Clinical characteristics of the study population are presented in Table 1.

TSH was significantly associated with BMI SDS ($p < 0.001$) adjusted for age and gender. No significant associations were observed between fT3 ($p = 0.17$) or fT4 ($p = 0.94$) and BMI SDS (Table 2). Consequently, when children with high-normal and low-normal TSH levels were compared, higher BMI SDS was found in the group with high-normal TSH levels (2.92 ± 0.45 vs. 3.00 ± 0.78 , $p < 0.001$). There were no significant differences in fT4 ($p = 0.63$) or fT3 levels ($p = 0.34$) between the groups (Table 1). We did not find any significant differences in mean TSH between genders ($p = 0.46$). However, girls had lower fT3 (5.95 ± 1.03 vs. 6.26 ± 1.06 mU/L, $p < 0.001$) as well as BMI SDS (2.89 ± 0.45 vs. 2.99 ± 0.45 , $p < 0.001$) than boys (data not shown).

When the severely obese and moderately obese groups were compared, higher levels of TSH were found in the severely obese (2.57 ± 0.93 vs. 2.36 ± 0.89 mU/L, $p < 0.001$), but there were no differences regarding fT3 ($p = 0.10$) and fT4 ($p = 0.46$) levels between the groups. Consequently, the TSH/fT4 ratio was significantly higher in the severely obese group (Mann-Whitney U test, $p < 0.001$) (Table 1).

To study how TSH and thyroid hormones were associated with metabolic parameters, a multivariable regression analysis adjusted for age, gender, and BMI SDS was performed. TSH was significant positively associated with f-insulin ($p = 0.002$), HOMA ($p = 0.004$), total cholesterol ($p = 0.001$), and triglycerides ($p < 0.001$). fT3 was positively associated with f-insulin ($p = 0.013$), f-glucose ($p < 0.001$), and HOMA ($p = 0.003$) and inversely associated with total cholesterol ($p = 0.004$), and fT4 was inversely associated with total cholesterol ($p < 0.001$), triglycerides ($p < 0.001$), LDL ($p = 0.002$), and HDL ($p < 0.001$) (Table 2). After adjustment for fT3 and TSH simultaneously in the regression model, TSH remained associated with BMI SDS ($p = 0.003$), f-insulin ($p < 0.001$), and HOMA ($p = 0.001$), and the previously observed associations between fT3 and metabolic risk markers remained significant (f-insulin, $p = 0.010$; f-glucose, $p < 0.001$; HOMA, $p = 0.003$; and total cholesterol, $p = 0.004$) (data not shown).

Multivariable regression stratified by age groups and adjusted for gender showed positive associations between BMI SDS and TSH in all age groups (age 3–6.9 years, $p = 0.015$; age 7–11.9 years, $p < 0.001$; and age 12–17.9 years, $p = 0.001$). BMI SDS was associated with fT3 in the oldest age group ($p = 0.020$), and BMI SDS was not associated with fT4 in any of the age groups (Table 3). Similar results were observed when the model was stratified by pubertal status (data not shown).

In the age group 7–11.9 years, TSH was significantly associated with total cholesterol ($\beta = 0.05$; 95% CI: 0.01–

Table 3. Multivariable regression analysis of the impact of BMI SDS (independent variable) on TSH, fT3, and fT4 (dependent variables), controlling for gender

	<i>n</i>	BMI SDS (3–6.9 years)	BMI SDS (7–11.9 years)	BMI SDS (12–17.9 years)
TSH	381/1,474/1,604	0.20 (0.04 to 0.36)*; R^2 0.01	0.25 (0.13–0.37)**; R^2 0.01	0.19 (0.08 to 0.29)*; R^2 0.01
fT3	60/337/690	0.07 (–0.65 to 0.40)	–0.03 (–0.30 to 0.24)	–0.22 (–0.40 to –0.04)*; R^2 0.08
fT4	308/1,212/1,394	–0.28 (–0.71 to 0.14)	–0.13 (–0.52 to 0.25)	–0.04 (–0.31 to 0.40)

Data are presented as β coefficient (95% CI). TSH, thyroid-stimulating hormone; BMI SDS, body mass index standard deviation scores; fT3, free triiodothyronine; fT4, free thyroxine. * $p < 0.05$, ** $p < 0.001$, with adjusted Pearson correlation coefficient (R^2).

0.10; $p = 0.018$) and triglycerides ($\beta = 0.08$; 95% CI: 0.05–0.12; $p < 0.001$). In the oldest age group (12–17.9 years), we found significant associations with f-insulin ($\beta = 1.30$; 95% CI: 0.48–2.11; $p = 0.003$), HOMA ($\beta = 0.31$; 95% CI: 0.10–0.32; $p = 0.006$), total cholesterol ($\beta = 0.06$; 95% CI: 0.01–0.10; $p = 0.027$), triglycerides ($\beta = 0.06$; 95% CI: 0.03–0.10; $p = 0.001$), and HDL cholesterol ($\beta = 0.02$; 95% CI: 0.001–0.03; $p = 0.023$). TSH was not associated with any metabolic markers in the youngest age group (3–6.9 years) (data not shown).

Discussion

In this study of children from several obesity treatment clinics across Sweden, the levels of TSH and the degree of obesity were positively associated. This is, to the best of our knowledge, the largest study so far investigating TSH levels in children with obesity, and the results are in line with previous studies [17, 22, 28] but not with other smaller studies covering a narrower age range where no association between TSH and BMI SDS was observed [18, 19].

Within the obese individuals, we found associations of TSH with several markers of glucose metabolism as well as with lipid profile, which is in line with some previous studies [19, 21, 28] but not with others [10, 17]. One explanation for the contradictive results might be different sample sizes, different age ranges included, different TSH intervals used, or the inclusion of both overweight and obese subjects. Furthermore, we found associations of fT3 and fT4 with markers of both glucose metabolism and lipid profile, which is consistent with some [15, 22] and contradictive to other studies [28]. However, the associations of TSH, fT3, and fT4 with lipids were minor, and these associations should be followed up by further studies to clarify their clinical relevance.

We found that fT3, independently of TSH, was associated with higher f-glucose and lower total cholesterol and that both TSH and fT3 were, independently of each other, associated with higher f-insulin and consequently HOMA. This finding supports the notion that fT3 is an important mediator in energy metabolism under TSH regulation [29], although the causality of an elevated TSH in obesity together with a slight elevation of fT3 with no effect on fT4 levels is unclear, and the underlying mechanism is unknown.

It is unclear whether the compensatory increase in TSH level is due to increased metabolism or the disturbed production of thyroid hormones in the obese state, or whether obesity directly upregulates TSH secretion. An increase in physiologically inactive reverse T3 (rT3) has previously been seen in rats fed a high-fat diet whilst fT3 and fT4 remained unaltered [30]. It has been suggested that TSH became elevated due to overstimulation of the hypothalamic-pituitary-thyroid axis and that fT3 and fT4 remained unaltered or slightly changed due to altered peripheral deiodinase activity [30]. On the other hand, previous studies have shown that fT3 is higher in obese children than in normal-weight controls. It has therefore been suggested that obesity activates the thyroid axis to counteract the obesity by increasing resting energy expenditure or that fT3 is higher due to an increased turnover of thyroid hormones by altered deiodinase activity converting fT4 to fT3 [17, 31]. TSH in obesity seems to enhance fT3 production beyond the stimulation of the thyroid [29], and extra thyroidal T3 has been shown to fluctuate substantially with nutrient intake [32]. In normal-weight adults, deiodination of fT4 produces approximately equal amounts of fT3 and rT3, whereas in obese individuals rT3 but not fT3 has been shown to be reduced [25]. An increase in both TSH and fT4 has also been shown in rats fed a high-fat diet [33], suggesting that obesity directly induces TSH production. In the present study

TSH was increased in the severely obese group without any changes in fT3 or fT4 between the obese and severely obese groups, which could support the theory of increased rT3 production.

It is not yet clear whether changes in thyroid function even within the normal range might affect body weight. Previous studies have confirmed that there might be a direct effect of TSH in the adipose tissue via adipocyte TSH receptors (TSHr) [34, 35] independently of its effect on thyroid function. Previously, TSH acting on TSHr has been shown to be involved in regulating lipolysis in neonates [36], inducing adipogenesis in mouse embryonic stem cells [37], directly stimulating leptin secretion in human adipose tissue [38], and inducing differentiation of preadipocytes [39], supporting the hypothesis that there is a relationship between adipose tissue and TSH. In theory, the regulation of thyroid function could be impaired due to a reduction of TSHr in the adipose tissue of obese individuals. In addition to the proposed adipose tissue mechanisms, plasma TSH and/or fT3 have been suggested to be increased to cope with peripheral hormone resistance, thereby affecting the feedback regulation of thyroid hormones [40]. We found elevated TSH in the presence of normal free thyroid hormones, which might indicate that the negative feedback regulation of TSH in our obese population is unaffected and that elevated TSH levels are required to maintain normal thyroid hormone levels.

Stratifying the cohort for age according to age-specific TSH reference ranges showed no associations of TSH with any of the metabolic parameters in the youngest group. It is possible that the physiological mechanism of TSH and its associations with lipids and glucose metabolism develop slowly and might therefore not yet be fully developed in children [28], or that the youngest children are less affected metabolically since TSH was associated with the degree of obesity in all ages with the same explanatory degree (R^2). Only in the oldest age group was fT3 associated with BMI SDS, whereas no association was observed between BMI SDS and fT4.

Strengths and Limitations

This is a large nationwide study based on data from the Swedish Childhood Obesity Treatment Registry (BORIS), supervised by the National Board of Health and Welfare. The large sample allowed us to investigate TSH levels within age-specific ranges, which is important since normal TSH ranges differ between age intervals. It is therefore preferable to look at each specific normal range, not only adjusting for age in the statistical analysis. However, our study has limitations.

This is a retrospective cross-sectional examination and a prospective design would have been preferable. Thus, no causal relationship can be determined. Varying TSH assays for analysis were used due to the children being enrolled from clinics all over Sweden for several years. All samples were, however, analyzed by certified laboratories. Different cutoffs for elevated TSH are used in previous publications, which makes it difficult to directly compare results to previous studies. In addition, the cutoff for “high-normal TSH” is under debate. An elevated TSH level is in some studies described as 4.0–10.0 mU/L [24, 41], whilst others suggest that the limit should be lowered [42]. Recently, TSH >3.0 mU/L is described as elevated within the normal range [31] and supports the cutoff chosen in the present study.

Conclusions

The results confirm an association between TSH and BMI SDS within a cohort of children with obesity, where an elevated TSH level was associated with an increased degree of obesity in children. As the TSH levels were elevated the fT3 and fT4 levels remained unaltered. It is therefore concluded that an elevated TSH is needed to maintain normal thyroid hormone levels in the obese state. Furthermore, a disturbed glucose and lipid metabolism is associated with increased TSH levels. However, further longitudinal studies are necessary to clarify whether TSH and thyroid hormones contribute to obesity co-morbidities or whether the metabolic consequences of obesity affect thyroid hormone production and turnover in children with obesity.

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Disclosure Statement

The authors have no conflicts of interest to disclose.

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