Association of Socioeconomic Status with Iodine Supply and Thyroid Disorders in Northeast Germany

Henry Völzke,1 Clara Craesmeyer,1 Matthias Nauck,2 Harald Below,3 Axel Kramer,3 Ulrich John,4 Sebastian Baumeister,1 and Till Ittermann1

Objectives: Studies on the potential association of socioeconomic status with iodine supply and the risk for thyroid disorders from developed countries are sparse. Socioeconomic status, however, may particularly impact the efficiency of iodine prophylaxis programs, which are based on the voluntary principle. This study aims to investigate whether the socioeconomic status is cross-sectionally and longitudinally related to low urinary excretion or thyroid disorders in the population of northeast Germany.

Methods: Data of the population-based Study of Health in Pomerania were used. The study population comprised 4056 adults for cross-sectional and 2860 adults for longitudinal analyses. Assessment of socioeconomic status comprised different scales of education, income, employment, and occupation. Thyroid-related outcomes included urinary iodine excretion, serum thyrotropin, and sonographically defined goiter and nodules. Statistical analyses were adjusted for confounders.

Results: Some of the socioeconomic variables were associated with thyroid-related characteristics in cross-sectional analyses. For example, there was an overall tendency for groups with higher education and higher income to have larger thyroid volumes and an increased risk of goiter. However, most of these associations did not attain statistical significance after correcting the target \( p \)-value for multiple testing. Longitudinal analyses did not demonstrate consistent results.

Conclusions: Socioeconomic status neither substantially influences iodine supply nor does it have a major impact on the prevalence and incidence of thyroid deficiency–related disorders in the adult population of northeast Germany, indicating a good efficacy of the German iodine fortification program in all socioeconomic groups.

Introduction

Iodine deficiency–related disorders can effectively be prevented by improving the iodine supply of populations (e.g., through iodine fortification of nutrients). Many regions recently overcame their natural iodine deficiency by successfully implementing iodine fortification or supplementation programs. Indeed, iodine fortification programs belong to the most effective preventive programs that have ever been applied to general populations.

Iodine deficiency has a well-established socioeconomic component. It has been demonstrated that severe iodine deficiency is particularly prevalent in poor and less-educated people living in less-developed countries. Previously, such findings have been shown in African (1) and Asian (2,3) populations.

In many regions of the world, iodine fortification programs are based on the voluntary principle. Besides poverty, a low education level is one of the strongest predictors of reduced efficacy of such programs. A South African study (4) confirmed the expectation that subjects from low socioeconomic status households were less informed about iodine deficiency–related disorders than subjects from high socioeconomic status households. In countries with iodine prevention programs, education of adults is not only associated with better iodine supply in these adults, but also with the iodine supply and risk of iodine deficiency–related disorders in their children. This holds true even among the poorest: a mother’s education is the strongest predictor of inadequately low iodine intake in children from urban slums and rural areas, as a study from Indonesia demonstrated (5).

From developed European countries with voluntary iodine prophylaxis programs, data on the association between socioeconomic status and thyroid disorders are sparse. On the one hand one may hypothesize that a low education level is associated with inadequate iodine supply like in other, less-
developed countries. On the other hand, some higher educated individuals may be skeptical about iodine fortification. Indeed, so-called “iodine enemies” actively propagate potential risks of iodized table salt in Germany, using a mixture of mostly non-science-based statements to oppose the iodine prevention policy (6). For example, they argue that iodine may induce allergies and acne, or may even exert toxic effects, without considering the dose dependency of such risks. These activities may lead to a decreased iodine supply in better educated people. A similar phenomenon can also be observed for vaccination rates, which are lower among German individuals with a higher socioeconomic status than in those with a lower socioeconomic status (7).

For health policy makers, it would not only be helpful to learn more about socioeconomic differences in iodine supply within populations, but also to gain insights into the longitudinal relationships between the socioeconomic status and change in iodine supply, as well as its effects on the individual risk of iodine deficiency–related disorders over time. Such findings can only be derived from cohort studies, but, unfortunately, longitudinal studies on the socioeconomic impact of thyroid disorders are not available.

With this background, we investigated the association of indicators of the socioeconomic status with urinary iodine excretion and thyroid disorders in the general adult population from northeast Germany. We analyzed whether socioeconomic status is related to low urinary excretion or thyroid disorders cross-sectionally. In addition we longitudinally investigated whether a change in the individual socioeconomic status is related to a change in urinary excretion and an altered risk of thyroid disorders.

Subjects and Methods

Study population

The Study of Health in Pomerania (SHIP) is a population-based research project in West Pomerania, a region in the northeast of Germany. Study details are given elsewhere (8). West Pomerania is located in the region of the former German Democratic Republic (GDR), where a mandatory iodine prophylaxis was introduced in the mid-1980s, but collapsed with the German reunification in the 1990s. From the mid-1990s onwards, a nationwide iodine fortification program was implemented in the region of the former GDR, where a mandatory iodine prophylaxis was introduced in the mid-1980s, but collapsed with the German reunification in the 1990s. From the mid-1990s onwards, a nationwide iodine fortification program was implemented.

From the total population of West Pomerania comprising 212,157 inhabitants, a sample of adults aged 20 to 79 years was drawn from population registries. Data collection for baseline examinations (SHIP-0) started in October 1997 and ended in March 2001. The net sample comprised 6265 eligible subjects, and 4308 subjects (2193 women, 2115 men) participated (response 68.8%). Between 2002 and 2006 all participants were re-invited for follow-up examinations (SHIP-1), in which 3300 subjects (83.5% of still living persons that could be contacted, 1709 women) took part (9,10).

The present cross-sectional analyses are based on SHIP-0 data. All subjects who took iodine medication (n = 91) or had missing values for outcome variables or potential confounders (n = 161) were excluded, leaving a cross-sectional SHIP study population of 4056 subjects (2033 women) for the present analysis. For longitudinal analyses, we used data from all individuals who participated in SHIP-0 and SHIP-1. From these 3300 subjects we excluded again participants who reported iodine intake in either SHIP-0 or SHIP-1 (n = 328) or had missing values for outcome or confounder variables (n = 112). Thus, the study population for longitudinal analyses comprised 2860 subjects (1412 women). From analyses for specific socioeconomic variables, subjects with missing values for each of the socioeconomic variables were further excluded as indicated.

SHIP conformed to the principles of the Declaration of Helsinki as reflected by a priori approvals of the local Ethics Committees. All participants signed the written informed consent.

Measurements

Computer-assisted personal interviews were conducted by trained staff. To define socioeconomic status, we used measures of educational attainment, income, and occupational prestige as indicators of the socioeconomic position (11). Education was categorized into three sections according to the German school system (low, < 10 years; intermediate, 10 years; and high, > 10 years). Monthly household per capita net income was categorized into $< 600, 600–900, > 900–1200, and > 1200 €. We applied a commonly adopted procedure to divide the household income by the square root of the number of household members, thus assuming an equivalence parameter of 0.5 (12). Occupations were coded according to the system of the International Labour Association and converted into two occupational prestige scales: the International Socioeconomic Index of Occupational Status (ISEI) and the Standard International Occupational Prestige Scale (SIOPS) (13,14). The ISEI scores occupations on a scale ranging from 10 to 90 points, with unskilled farm workers assigned the lowest score and judges assigned the highest score. Prestige measures as the SIOPS are generated from popular evaluation of occupational standings. They reflect the idea that occupations are used as a primary device to interpret and label the social position of an interaction partner. The SIOPS ranges from 14 to 80; higher values indicate higher prestige.

Information on the current use of drugs was classified according to the anatomic, therapeutic, and chemical (ATC) code. From a food questionnaire (15), we selected the frequency of consumption of eggs, milk, bread, meat, and sea fish, which are the most relevant sources of iodine in Europe (16).

Urinary iodide concentrations were measured from spot urine samples. Iodine concentrations were evaluated by a photometric procedure (Photometer ECOM 6122, Eppendorf, Hamburg, Germany) with the Sandell and Kolthoff reaction (17). Urinary creatinine concentrations were determined according to the Jaffe method (SHIP-0: Hitachi 717, Roche Diagnostics, Mannheim, Germany; SHIP-1: Dimension RXL, Siemens, Munich, Germany). The limit of detection was 1μg/L. Coefficients of variation were 9.3% at 50μg/L, 2.1% at 100μg/L, 1.9% at 200μg/L, and 4.2% at 300μg/L. The iodine/creatinine ratio was calculated by dividing urinary iodine by urinary creatinine concentration. In addition we computed age- and sex-adjusted iodine/creatinine ratio using the formula [iodine (μg/L)]/creatinine (g/L)/expected creatinine excretion (g/d). The expected creatinine 24-h excretion values were calculated according to Kesteloot and Joossens (18).

Blood samples were taken, and laboratory parameters were analyzed in one central laboratory. In the baseline SHIP...
investigations, serum thyrotropin (TSH) levels were measured by an immunochromiluminescent procedure (LIA-mat, Byk Sangtec Diagnostica GmbH, Frankfurt, Germany). The functional sensitivity of the TSH assay was 0.03 mIU/L. The reference range recently established for the SHIP region was 0.25–2.12 mIU/L for TSH (19). TSH levels <0.25 mIU/L were considered decreased and levels >2.12 mIU/L, increased. At follow-up, serum TSH was similarly analyzed by an immunochromiluminescent method (Immulite 2000, Third generation, Diagnostic Products Corporation [DPC], Los Angeles, CA). Comparisons between the DPC and Byk Sangtec assays revealed a regression equation according to Passing-Bablock of $y = 1.029x - 0.032$ mIU/L for TSH (20). All serum TSH levels from the follow-up investigation were corrected using this formula. Coefficients of variation for TSH were 5.0% at 0.3 mIU/L, 3.7% at 16.1 mIU/L, and 8.9% over the whole study period.

In the SHIP-0 and SHIP-1 examinations thyroid ultrasound was performed using an ultrasound VST-Gateway with a 5-MHz linear array transducer (Diasonics, Santa Clara, CA). Thyroid volume was calculated as length $\times$ width $\times$ depth $\times$ 0.479 (mL) for each lobe (21). The intra- and interobserver reliabilities were assessed before starting data collection and semi-annually during the study. All measurements of the thyroid volume showed mean differences ($\pm$2 SD) of the mean bias of $<5\% (<25\%)$ (22). To warrant best possible comparability between baseline and follow-up data, all examinations were conducted using the same devices, which were checked weekly by phantom measurements. Thyroid volume progression was defined as difference between follow-up and baseline thyroid size. Goiter was defined as a thyroid volume >18 mL in women and >25 mL in men (23). Nodular changes >10 mm in diameter were defined as nodules.

**Statistical analysis**

Data on quantitative characteristics are expressed as median and interquartile range. Data on qualitative characteristics are expressed as percent values or absolute numbers as indicated. Comparisons between men and women were made using the chi-square test (qualitative data) or Wilcoxon test (quantitative data). Multivariable analyses of cross-sectional data were performed by median (continuous outcomes) and logistic regressions (dichotomous outcomes), which allowed the adjustment for age, sex, smoking status, and intake of eggs, milk, and fish. Results of the cross-sectional regression models are expressed as $\beta$ and 95% confidence interval (CI); continuous outcomes and as odds ratio and 95% CI.

For longitudinal analysis we modeled the change between baseline and follow-up (continuous outcomes) by median regression and the incidence of an event (dichotomous outcomes) by Poisson regression with robust standard errors. All analyses were adjusted for time between baseline and follow-up examination as well as baseline values of age, sex, smoking status, and intake of eggs, milk, and fish. Since baseline sociodemographic variables were significantly associated with dropout to follow-up, we applied inverse probability weights based on baseline sociodemographic and health-related variables in our longitudinal analysis. The results of the longitudinal regression models are expressed as $\beta$ and 95% CI (continuous outcomes) and as relative risk and 95% CI (dichotomous outcomes). For all continuous exposure variables, fractional polynomials up to a degree of 2 were tested to account for a possible nonlinear relation between exposure and outcome (24). Transformation of the exposure variable was not needed in any of our analyses. For each binary outcome, we excluded all prevalent cases from incidence analyses. Thus, dependent of the prevalence of the investigated disorder, the study population for incidence analyses ranged from $n = 1806$ (urinary iodine excretion <100 $\mu$g/L) to $n = 2653$ (decreased serum TSH levels).

A value of $p < 0.05$ was considered statistically significant. All calculations were performed using STATA 12.0 (Stata Corporation, College Station, TX).

**Results**

Men and women differed with respect to a number of characteristics (Table 1). Compared to women, men were older, had less often a 10-year school education and a higher income, were more commonly senior citizens, had lower values on the ISEI and SIOPS scales, were more current smokers or ex-smokers. Men consumed more frequently eggs during the past week, but less frequently milk than women. Urinary iodine excretion and the adjusted urinary iodine/creatinine ratio were higher, whereas the unadjusted urinary iodine/creatinine ratio was lower in men than in women. Finally, men had larger thyroids, but a lower frequency of nodules and lower serum TSH levels than women.

In the multivariable analysis of the cross-sectional data, we did not detect any interaction between sex and any of the socioeconomic variables with respect to thyroid-related outcomes. Therefore all multivariable analyses were calculated for the entire study population (Table 2).

We did not find significant associations of any of the socioeconomic variables with iodine excretion, thyroid nodules, and serum TSH levels with two exceptions. First, unemployed subjects had higher serum TSH levels than those that were employed. Second, the income category 900–1200 € was associated with lower serum TSH levels, but the proportion of subjects having decreased serum TSH levels was similar across these groups.

In contrast, there were some associations of socioeconomic variables with thyroid volume and goiter (Table 2). There was an overall tendency in better educated and higher income groups towards larger thyroid volumes and increased risks of goiter. With regard to the employment status, senior citizens had lower thyroid volumes and a lower risk of goiter than employed subjects. The occupational status was not related to thyroid size. However, when lowering the significance level to $p < 0.001$ for taking into account multiple testing according to Bonferroni ($p < 0.05$ divided by the number of tests), only the association of equivalent income with thyroid volume and goiter remained statistically significant.

Longitudinal analyses yielded no consistent associations between socioeconomic and thyroid-related variables (Table 3). Although a high education level was related to lower urinary iodine excretion, it was associated with a lower incidence of decreased serum TSH levels. Furthermore, moderate income was associated with a lower risk of thyroid nodules, and a higher ISEI with a slightly higher risk of urinary iodine excretion <100 $\mu$g/L. None of the other socioeconomic variables, which were cross-sectionally associated with thyroid-related outcomes, were also related to the longitudinal change...
or the incidence of thyroid-related outcomes. Except for the association between high education and urinary iodine excretion <100 µg/L, none of the longitudinal associations provided in Table 3 attained statistical significance after adjusting the target \( p \)-value for multiple testing.

For sensitivity analyses, we varied some exposure and outcome variables. These analyses arrived at similar results; some associations were detected in the cross-sectional data, but none of the analyses reached statistical significance in the longitudinal data. For example, when using the adjusted iodine/creatinine ratio instead of crude urinary iodine excretion, multivariable models revealed that education >10 years and higher equivalent incomes were associated with higher values in the cross-sectional data and senior citizenship with lower values, but not in the longitudinal data. Furthermore, alternate cut-offs for defining decreased serum TSH levels (e.g., 0.3 and 0.4 mIU/L) did not substantially change the results presented in Tables 2 and 3. Finally, variation of confounders and additional inclusion of alcohol consumption did not affect these results.

**Discussion**

This study investigated putative associations between socioeconomic variables and iodine deficiency–related outcomes in a Central European population. The overall question was whether there are socioeconomic determinants of iodine deficiency–related disorders in a general adult population living in a region with a voluntary iodine fortification program. In our cross-sectional analyses we found weak associations of some of the socioeconomic variables with thyroid volume and goiter. These results, however, were not consistent over all analyses or present for other iodine deficiency-related disorders, and they mostly did not remain statistically significant after correcting the \( p \)-value for multiple testing.

None of these associations were consistently present in the longitudinal data. These findings indicate that socioeconomic factors do not substantially influence the risk of thyroid disorders in the investigated population.

Low socioeconomic status is strongly related to behavior choices such as smoking or diet (25), and in general it is a great challenge for many preventive programs to address low socioeconomic classes (26). One of the main reasons for the success of the prevention of iodine deficiency–related health disorders is the high reach of iodized food (27). As in many countries, this has been achieved in Germany by use of iodine fortification of table salt and cattle feed. The consumer has the choice between iodized and noniodized salt, but iodine-fortified salt is available in nearly every food store. Noniodized salt is now offered as Himalaya salt or Fleur de Sel in high-
### Table 2. Cross-Sectional Analyses on the Association Between Socioeconomic Variables and Iodine Deficiency-Related Outcomes

<table>
<thead>
<tr>
<th>Education</th>
<th>Urinary iodine, µg/L</th>
<th>Urinary iodine &lt; 100 µg/L</th>
<th>Thyroid volume, mL</th>
<th>Goiter</th>
<th>Thyroid nodules</th>
<th>TSH, U/L</th>
<th>Decreased TSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10 years</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>10 years</td>
<td>1.87 [−5.58–9.32]</td>
<td>0.97 [0.82–1.15]</td>
<td>0.78 [0.18–1.39]*</td>
<td>1.22 [1.03–1.45]*</td>
<td>1.12 [0.91–1.37]</td>
<td>−0.01 [−0.04–0.03]</td>
<td>1.06 [0.79–1.42]</td>
</tr>
<tr>
<td>&gt;10 years</td>
<td>−3.08 [−12.40–6.23]</td>
<td>1.04 [0.84–1.28]</td>
<td>0.80 [0.04–1.56]*</td>
<td>1.13 [0.91–1.41]</td>
<td>1.20 [0.93–1.55]</td>
<td>0.01 [−0.03–0.06]</td>
<td>0.72 [0.47–1.09]</td>
</tr>
<tr>
<td>Equivalent income (€), SD</td>
<td>−0.74 [−3.81–2.32]</td>
<td>1.00 [0.94–1.07]</td>
<td>0.49 [0.26–0.72]*</td>
<td>1.13 [1.06–1.21]*</td>
<td>1.04 [0.96–1.13]</td>
<td>−0.01 [−0.02–0.00]</td>
<td>0.95 [0.83–1.08]</td>
</tr>
<tr>
<td>Equivalent income</td>
<td>&lt;600 €</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>600–&lt;900 €</td>
<td>−4.10 [−14.53–6.33]</td>
<td>0.96 [0.79–1.17]</td>
<td>0.56 [−0.18–1.31]</td>
<td>1.16 [0.94–1.42]</td>
<td>1.08 [0.85–1.38]</td>
<td>−0.00 [−0.04–0.04]</td>
<td>1.31 [0.92–1.87]</td>
</tr>
<tr>
<td>900–1200 €</td>
<td>−6.61 [−17.04–3.82]</td>
<td>1.08 [0.89–1.31]</td>
<td>1.13 [0.38–1.87]*</td>
<td>1.36 [1.11–1.66]*</td>
<td>1.09 [0.86–1.39]</td>
<td>−0.04 [−0.08–0.00]*</td>
<td>0.96 [0.67–1.38]</td>
</tr>
<tr>
<td>&gt;1200 €</td>
<td>−1.39 [−11.77–3.99]</td>
<td>0.97 [0.80–1.18]</td>
<td>1.04 [0.30–1.79]*</td>
<td>1.35 [1.11–1.65]*</td>
<td>1.05 [0.82–1.35]</td>
<td>−0.02 [−0.06–0.02]</td>
<td>1.05 [0.72–1.52]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Employment status</th>
<th>Urinary iodine</th>
<th>Change in thyroid volume, mL</th>
<th>Goiter</th>
<th>Thyroid nodules</th>
<th>Change in TSH, U/L</th>
<th>Decreased TSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employed</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>Unemployed</td>
<td>−0.60 [−9.60–8.40]</td>
<td>1.10 [0.91–1.34]</td>
<td>−0.56 [−1.25–0.13]</td>
<td>0.87 [0.71–1.07]</td>
<td>1.00 [0.77–1.29]</td>
<td>0.07 [0.03–0.11]*</td>
</tr>
<tr>
<td>Senior citizen</td>
<td>8.00 [−2.39–18.39]</td>
<td>0.99 [0.79–1.24]</td>
<td>−1.24 [−2.03 to −0.44]*</td>
<td>0.76 [0.61–0.95]*</td>
<td>1.08 [0.82–1.41]</td>
<td>0.04 [−0.00–0.09]</td>
</tr>
<tr>
<td>ISEI/SD</td>
<td>−0.21 [−3.15–2.74]</td>
<td>1.01 [0.94–1.08]</td>
<td>0.10 [−0.13–0.32]</td>
<td>1.03 [0.96–1.10]</td>
<td>1.00 [0.92–1.08]</td>
<td>−0.01 [−0.02–0.01]</td>
</tr>
<tr>
<td>SIOFS/SD</td>
<td>0.37 [−2.55–3.30]</td>
<td>0.97 [0.91–1.04]</td>
<td>0.11 [−0.10–0.32]</td>
<td>1.03 [0.96–1.10]</td>
<td>1.00 [0.93–1.08]</td>
<td>−0.01 [−0.02–0.01]</td>
</tr>
</tbody>
</table>

Data are β values and [95% confidence intervals] (continuous outcomes) or odds ratios and [95% confidence intervals] (binary outcomes). Median regression models were applied to continuous outcomes, logistic regression models to binary outcomes. All models were adjusted for age, sex, smoking status, and intake of eggs, milk, and fish.

*<p<0.05.

SD, standard deviation.

### Table 3. Longitudinal Analyses on the Association Between Socioeconomic Variables and Iodine Deficiency-Related Outcomes

<table>
<thead>
<tr>
<th>Education</th>
<th>Change in urinary excretion levels, µg/L</th>
<th>Urinary iodine &lt; 100 µg/L</th>
<th>Change in thyroid volume, mL</th>
<th>Goiter</th>
<th>Thyroid nodules</th>
<th>Change in TSH, U/L</th>
<th>Decreased TSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10 years</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>10 years</td>
<td>−10.07 [−23.10–2.96]</td>
<td>1.11 [0.93–1.33]</td>
<td>0.64 [0.03–1.25]*</td>
<td>0.94 [0.71–1.25]</td>
<td>0.96 [0.66–1.42]</td>
<td>−0.02 [−0.07–0.02]</td>
<td>1.15 [0.61–2.17]</td>
</tr>
<tr>
<td>&gt;10 years</td>
<td>−17.55 [−32.82 to −2.27]*</td>
<td>1.41 [1.15–1.72]*</td>
<td>−0.22 [−0.91–0.46]</td>
<td>0.95 [0.67–1.33]</td>
<td>0.84 [0.51–1.38]</td>
<td>−0.00 [−0.06–0.05]</td>
<td>0.34 [0.13–0.90]*</td>
</tr>
<tr>
<td>Equivalent income (€), SD</td>
<td>−1.41 [−5.55–2.72]</td>
<td>1.02 [0.95–1.09]</td>
<td>−0.16 [−0.40–0.07]</td>
<td>0.96 [0.86–1.08]</td>
<td>1.04 [0.89–1.21]</td>
<td>−0.01 [−0.03–0.02]</td>
<td>0.89 [0.71–1.13]</td>
</tr>
<tr>
<td>Equivalent income</td>
<td>&lt;600 €</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>600–&lt;900 €</td>
<td>−7.69 [−23.27–7.88]</td>
<td>1.04 [0.86–1.26]</td>
<td>−0.29 [−0.87–0.28]</td>
<td>0.99 [0.71–1.38]</td>
<td>0.78 [0.51–1.18]</td>
<td>0.06 [−0.00–0.12]</td>
<td>1.73 [0.73–4.12]</td>
</tr>
<tr>
<td>900–1200 €</td>
<td>−2.59 [−18.75–13.38]</td>
<td>1.04 [0.85–1.26]</td>
<td>−0.16 [−0.79–0.46]</td>
<td>1.09 [0.79–1.59]</td>
<td>0.38 [0.38–0.91]*</td>
<td>0.04 [−0.02–0.09]</td>
<td>1.69 [0.71–4.01]</td>
</tr>
<tr>
<td>&gt;1200 €</td>
<td>−6.94 [−22.43–8.54]</td>
<td>1.11 [0.92–1.34]</td>
<td>−0.39 [−0.98–0.19]</td>
<td>0.95 [0.69–1.31]</td>
<td>0.92 [0.61–1.38]</td>
<td>0.03 [−0.00–0.12]</td>
<td>1.08 [0.45–2.59]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Employment status</th>
<th>Change in TSH, U/L</th>
<th>Decreased TSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employed</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>Unemployed</td>
<td>−4.01 [−19.58–11.55]</td>
<td>0.98 [0.80–1.10]</td>
</tr>
<tr>
<td>Senior citizen</td>
<td>1.78 [−12.47–16.03]</td>
<td>0.93 [0.74–1.16]</td>
</tr>
<tr>
<td>ISEI, SD</td>
<td>−2.13 [−6.87–2.61]</td>
<td>1.07 [1.00–1.15]*</td>
</tr>
<tr>
<td>SIOFS, SD</td>
<td>−2.22 [−6.94–2.49]</td>
<td>1.06 [0.99–1.14]</td>
</tr>
</tbody>
</table>

Data are β values and 95% confidence intervals (continuous outcomes) or rate ratios and 95% confidence intervals (binary outcomes). Median regression models were applied to continuous outcomes (change between SHIP-0 and SHIP-1). Poisson regression models were applied to binary outcomes (incidence). All models were adjusted for baseline values of age, sex, smoking status, and intake of eggs, milk, and fish as well as for the time between SHIP-0 and SHIP-1 examinations. All analyses are weighted for loss to follow-up.

*p<0.05.
class market segments rather than in discount supermarkets and is remarkably more expensive than iodized salt. In addition, every food maker including bakeries, butchers, and caterers are allowed to use iodized salt without an extra declaration or content warning. Cattle feed is iodized to improve productivity. Consequently, milk is currently one of the most important sources of iodine intake in Germany. All of these measures may be particularly suited to solve one of the most outstanding limitations of prevention programs, which is socioeconomic status. Insofar, the German iodine fortification program may serve as a template for other countries, in which a socioeconomic gradient exists in iodine fortification programs.

When interpreting our findings, the regional history of iodine supply in the population of northeast Germany has to be taken into account. The SHIP study region is located in the area of the former GDR. There, a mandatory iodine fortification program of table salt and cattle feed led to a substantial increase of the iodine supply in the late 1980s (28). After the German reunification in 1990, the program was abruptly abandoned due to the adoption of the West German legislation, which was at that time insufficient to warrant an efficient iodine supply of the German population. In 1993, an improved legislation was established for the entire reunited Germany. This allowed voluntary iodine fortification of table salt and cattle feed without special declarations, which had been mandatory before. Consecutively, the iodine supply of the German population gradually increased during the mid-1990s. Current population studies demonstrate reiteratively a median urinary iodine excretion of between 100 and 200 μg/L (29–31).

The initial phase of the East German iodine fortification program was accompanied by information campaigns, and individuals were exposed to iodide-fortified food without experiencing side effects. This may have led to a broad acceptance of iodine fortification over all socioeconomic classes in East Germany. This notion is supported by findings from disparities in the acceptance of vaccinations between East and West German populations. While vaccination programs were mandatory in the former GDR and became voluntary after German reunification, they were based on the voluntary principle in West Germany throughout all the years. These different histories are still reflected by higher vaccination rates in the East German compared with the West German population (32–34). Of note, a study in 14,826 children demonstrated that reservations against measles vaccination were much more common in parents from West compared to East Germany, and high socioeconomic status was another important factor associated with lower vaccination rates and pronounced reservations against vaccination programs (35).

Thus, it has to be investigated whether the results presented herein can be generalized to the West German population or whether the situation in West Germany is similar to other countries, where iodine prophylaxis programs were based on the voluntary principle from the beginning. For example, as early as 1952, France introduced an iodine fortification program on a voluntary basis, but most French people are still living in a mildly to moderately iodine-deficient environment, and a nationwide study of adults demonstrated that higher education was related to a higher iodine intake (36). Similar findings were reported from South Africa (37) and Iran (38), where higher socioeconomic status was associated with more frequent use of iodized salt, higher urinary iodine excretion levels, and lower goiter risk. Likewise, a study from Madrid, Spain, demonstrated that children of less educated mothers had a lower iodine intake than children of better educated mothers (39).

Our cross-sectional analyses show an association of some of the socioeconomic variables with thyroid volume and goiter. Although these associations were independent of smoking status in our analyses, residual confounding might remain. In our longitudinal data, the associations did not persist. Indeed, we have demonstrated recently that smoking was an important risk factor for thyroid volume and goiter in our cross-sectional baseline data (22), but not in our follow-up data (40). These seemingly discrepant findings can be explained by the fact that smoking amplifies the individual iodine deficiency in a generally iodine-deficient environment, but not in an iodine-sufficient environment (41). Our baseline data were collected shortly after the German iodine fortification program became effective, whereas 5 years later, a more stable iodine supply has been achieved. Against this background, it might be clear why there was no association of any of the socioeconomic variables with thyroid volume and goiter in the longitudinal analyses.

Our study has some strengths, which include the population-based design, the longitudinal approach and the comprehensive characterization with respect to thyroid disorders. Furthermore, urinary iodine excretion levels were directly measured to assess the individual iodine supply, which has advantages over the estimation of iodine intake based on food questionnaires. Particularly for the investigation of socioeconomic factors, self-reported nutrition might be biased by low education, which might lead to an imprecise association between social status and thyroid disorders (42).

Notwithstanding the strengths of our study, at least two limitations also merit consideration. First, the present analyses were adjusted for information from a food frequency questionnaire (15). This questionnaire assesses only roughly the qualitative composition of nutrition rather than providing quantitative data on food intake. Therefore, we cannot unequivocally exclude residual confounding by nutrition in our analyses. Second, nearly 5% of all participants did not provide any information on their income, which may have biased our results. To account for further possible selection bias by loss to follow-up, all longitudinal analyses were weighted for baseline sociodemographic and health-related variables.

We conclude that the socioeconomic status does not substantially influence iodine supply, nor does it have a major impact on the prevalence and incidence of thyroid deficiency-related disorders in the adult population in northeast Germany. The findings indicate a good efficacy of the German iodine fortification program over all socioeconomic groups. Therefore, a preventive program on selected socioeconomic groups is not required. Due to the distinct histories of iodine prophylaxis in East and West Germany in the years before 1990, it still needs further investigation whether our findings are generalizable to western Germany and other industrialized countries with iodine fortification programs, which are based on the voluntary principle.

Acknowledgments

The work is part of the Community Medicine Research net (CMR) of the University of Greifswald, Germany, which is
funded by the Federal Ministry of Education and Research (BMBF 01ZZ9603 and 01ZZ0103), the Ministry of Cultural Affairs as well as the Social Ministry of the Federal State of Mecklenburg-West Pomerania. The CMR encompasses several research projects that share data from the population-based Study of Health in Pomerania (SHIP; www.medizin.uni-greifswald.de/cm). Statistical analyses were supported by the German Research Foundation (DFG Vo 955/10-2) and the Federal Ministry of Nutrition, Agriculture and Consumer’s Safety (BMELV 07HS003). We thank Dr. Christina Poethko-Müller from the Robert Koch-Institute Berlin for her valuable comments on epidemiologic data on vaccination rates.

Author Disclosure Statement

There are no conflicts of interest.

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