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Objective Coeliac disease may affect school performance due to its effect on cognitive performance and related health consequences that might increase school absenteeism. The aim of this study was to investigate whether children with coeliac disease performed differently on completion of ninth grade in school compared with children without coeliac disease.

Methods Analysis was performed on a population of 445,669 children born in Sweden between 1991 and 1994 of whom 1767 were diagnosed with coeliac disease. School performance at ninth grade was the outcome and coeliac disease was the exposure. Other covariates included sex, Apgar score at 5 min, small for gestational age, year of birth, family type, parental education and income.

Results There was no association between coeliac disease and school performance at ninth grade (adjusted coefficient -2.4, 95% CI 5.1 to 0.4). A weak association was established between late coeliac diagnosis and higher grades, but this disappeared after adjusting for parent socioeconomic conditions. Being small for gestational age affected performance negatively (adjusted coefficient -6.9, 95% CI 8.0 to 5.7). Grade scores were significantly lower in children living with a single parent (adjusted coefficient -20.6, 95% CI 20.9 to 20.2), compared with those with married/cohabiting parents. A positive association was found between scores at ninth grade and parental education and income.

Conclusion Coeliac disease diagnosis during childhood is not associated with poor school performance at ninth grade.

CrossMark


What is already known on this topic?

- Childhood chronic diseases are associated with increased risk of low school performance.
- Adulthood coeliac disease is associated with low cognitive ability.
- Coeliac disease is associated with several health consequences that may increase school absenteeism.

What this study adds?

- Childhood coeliac disease is not associated with school performance at ninth grade.
- A weak association was found between late coeliac disease diagnosis and high grades, but this disappeared after adjusting for socioeconomic conditions.
- The study confirms an association between low school performance and living in a single parent household, low parental education and low parental income.

INTRODUCTION

Current evidence suggests a link between health and educational achievements, even though this does not necessarily imply causation.1,2 Research on childhood health and school performance has shown that low birth weight has a negative impact on children’s intellectual capacity,3,4 as well as school achievements.6,7 Currie and Hyson point out that there are relatively few studies on the effect of health after birth and school performance due to a lack of suitable data.1 However, the few existing studies suggest such a relationship for several chronic diseases such as diabetes, sickle cell anaemia, seizure disorders, asthma and obesity.8,9,10 Coeliac disease is a chronic disorder occurring after birth, but often during childhood.10,11 Previously coeliac disease was considered rare, but it is now quite common, with an increasing occurrence in many populations. On average the prevalence is estimated to be about 1%, but considerably higher in some countries, with up to 3% in some population segments.11 Coeliac disease has a multifactorial aetiology, with genetics and gluten as necessary factors, but other environmental factors have been implicated.12-16 We have been unable to find any published studies on coeliac disease and school achievement. However, a few available closely related studies have investigated the effect of coeliac disease on adult intellectual ability and cognitive impairment.17-21

Coeliac disease has systemic effects, it mainly affects the gastrointestinal tract with enteropathy resulting in malabsorption. Today there is only one effective treatment, which is a lifelong strict gluten-free diet, and dietary compliance is challenging. Left untreated, the disease can generate a wide range of health consequences such as failure to thrive, nausea/vomiting, diarrhoea or obstipation, anaemia and fatigue.22-24 Many of these health problems can decrease school attendance and contribute to low school performance.

Several studies have shown coeliac disease to negatively influence the cognitive performance and intellectual ability of adult patients.25-28 In the USA, lower cognitive ability among the elderly with coeliac disease has been indicated.19 To our knowledge, no...
studies to date have looked at coeliac disease in relation to cognitive performance, intellectual ability or school performance in the child population.

Our hypothesis is that childhood coeliac disease negatively affects school performance at ninth grade. Performance at ninth grade is a good measure for overall school performance as these scores are used in determining transition into higher secondary school and as such are important for the entire educational trajectories. Thus, in our study we assessed school performance at ninth grade and how this differs between children with coeliac disease and those without, while adjusting for relevant health, demographic and socioeconomic factors.

METHODS

Study population and data availability

The study population consisted of all children born in Sweden between 1991 and 1994. Selection of this birth cohort was based on data availability. It is from 1991 that most cases were reported to the Swedish National Childhood Celiac Disease Register with a personal identity number, a requirement for linkage of registers. Since data were only available up to 2010, majority of these children had only completed ninth grade as the highest level of education.

A total of 506 357 children were identified, of whom 60 688 were excluded either as they were born outside Sweden and therefore lacked health data from birth, or because they lacked data on ninth grade scores (Figure 1). A total of 445 669 children were included in the analysis, of whom 1767 had coeliac disease diagnosed, as shown in figure 1.

Data were made available through the Swedish Initiative for Research on Microdata in the Medical and Social Sciences (Umeå SIMSAM Lab) hosting data up to 2010. This is a comprehensive database with selected data from Statistics Sweden, the National Board of Health and Welfare, and the Swedish National Childhood Celiac Disease Incidence Register. Statistics Sweden performed data linkage using personal identity numbers, but before delivery to us the data were anonymised.

Statistics Sweden’s Longitudinal Integration Database for Health Insurance and Labour Market (LISA database) provided information on the total population, parents’ education and income, and the Swedish National Agency for Education’s Pupil Register provided data on school grades. The National Board of Health and Welfare provided data on perinatal events through its Medical Birth Register.

Outcome

Grade scores on completion of the ninth year of compulsory school education were the outcome of interest. Compulsory school education is from first to ninth grades and each grade is equivalent to 1 year of schooling. A national examination is administered in the ninth year and final grade scores are calculated as the sum of the 16 best subject grades in the final year, using grading points. The grading points offer a summary of performance during the final compulsory school year, with grades ranging from 0 to 320 points. For every subject, students are assigned a grade ranging from 0 to 20, where 0 represents failure, 10 is E, 12 is D, 15 is C, 17.5 is B and 20 is A. The lowest obtainable score on all subjects is 0, implying that one has scored 0 in all the tested subjects, while the highest is 320, implying that one has scored 20 in all 16 subjects.

Independent variable: coeliac disease cases

A total of 1767 children with coeliac disease were identified from all the 47 paediatric units in the country by accessing

![Figure 1](image)

Selection of the study population.

### Table 1

The study population with mean scores at ninth grade completion (with SDs) given for each child and parental characteristics, for coeliac disease and non-coeliac disease children

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean grades (SD) Coeliac Disease (n=1767)</th>
<th>Non-coeliac Disease (n=443 902)</th>
<th>Total number</th>
</tr>
</thead>
<tbody>
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<td>Sex</td>
<td>Male 198 (62.5) 651</td>
<td>226 963</td>
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<td>Female 220 (64.8) 1116</td>
<td>216 939</td>
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<td>&lt;7 206 (64.8) 12</td>
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<td>418 598</td>
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<tr>
<td></td>
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<td>3290</td>
<td>10 096</td>
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<td>13–15 220 (62.1) 290</td>
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<td>114 225</td>
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<tr>
<td></td>
<td>1994 210 (64.3) 316</td>
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<td>&lt;2 years university 219 (58.9) 143</td>
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<td>≥2 years university 231 (58.5) 741</td>
<td>185 437</td>
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<td>Mother’s income</td>
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<td>Middle 206 (62.2) 607</td>
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<td>High 223 (62.1) 634</td>
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<td>150 961</td>
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<td>Father’s income</td>
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<td>Middle 206 (60.1) 653</td>
<td>146 966</td>
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<tr>
<td></td>
<td>High 229 (57.9) 622</td>
<td>149 310</td>
<td>149 932</td>
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</table>
the Swedish National Childhood Celiac Disease Incidence Register.\textsuperscript{36} Ascertainment of celiac disease status was based on the 1990 diagnostic criteria by ESPGHAN (the European Society for Paediatric Gastroenterology, Hepatology and Nutrition). This implies that celiac disease is ascertained by a biopsy assessment of the small intestinal mucosa showing an enteropathy on a gluten-containing diet, followed by a clinical improvement after a change to a gluten-free diet. Child age at the coeliac diagnosis affected the performance at ninth grade.

We included parental characteristics that previous studies have considered to be strongly associated with school performance and educational attainment.\textsuperscript{28–30} Initially, we planned to include maternal and paternal educational levels as two separate variables, but due to a strong correlation categorisation was based on the highest education of the mother or the father. This variable was divided into four groups: compulsory education (reference), upper secondary education, <2 years of university education and $\geq$2 years of university education. Maternal and paternal disposable income at the child’s completion of ninth grade (per 100 SEK) was categorised into tertiles. The groups were labelled low (reference), middle and high (information was missing for fathers’ income for 4% and mother’s income for 2%). Type of family was categorised into two groups: married/cohabiting and single for all those living alone, that is, widows, widowers, divorced, separated and never married.

### Covariates: other characteristics

Variables were selected if they had been previously suggested to be associated with both health and school achievements. For child characteristics we included the following: sex, small for gestational age, Apgar score at 5 min (a measure of the newborn’s physical condition 5 min after birth) and year of birth. Sex was grouped into female and male, and there were no missing data. Apgar score at 5 min was categorised according to established criteria into low if the score was <7 and normal if the score was within the range of 7–10. Data were missing for 7%. Small for gestational age was precategorised into two groups (yes and no) according to the Swedish weight-based growth standards. Children are classified as small for gestational age if birth weight is 2 SD below the mean at a certain pregnancy length and not small for gestational age if otherwise. Data were missing for 9%. Year of birth ranged from 1991 to 1994, and this information was available for all children.

We included parental characteristics that previous studies have considered to be strongly associated with school performance and educational attainment.\textsuperscript{28–30} Initially, we planned to include maternal and paternal educational levels as two separate variables, but due to a strong correlation categorisation was based on the highest education of the mother or the father. This variable was divided into four groups: compulsory education (reference), upper secondary education, <2 years of university education and $\geq$2 years of university education. Maternal and paternal disposable income at the child’s completion of ninth grade (per 100 SEK) was categorised into tertiles. The groups were labelled low (reference), middle and high (information was missing for fathers’ income for 4% and mother’s income for 2%). Type of family was categorised into two groups: married/cohabiting and single for all those living alone, that is, widows, widowers, divorced, separated and never married.

### Statistical analysis

The multiple linear regression procedure was used to assess how well celiac disease predicted ninth grade scores. Other studied covariates were added step-by-step to assess any confounding, and this was done by running four models separately. Model 1 consisted of a celiac disease status alone. In model 2, the child’s demographic factors were added (sex, year of birth). In model 3, child’s health factors (Apgar score and small for gestational age) were added. In model 4, family type, parental education, and mother and father’s income were added. In a separate analysis that only included celiac disease cases, we checked whether age at diagnosis of celiac disease affected the performance at ninth

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**Table 2** Impact of coeliac disease on school achievement at ninth grade completion, taking child and parental characteristics into account

<table>
<thead>
<tr>
<th>Child and parental characteristics</th>
<th>Model 1</th>
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<th>Model 2</th>
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<th>Model 3</th>
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<td>95% CI</td>
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<td>22.2 to 22.9</td>
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<td>−1.1 to −0.1</td>
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</table>

Model 1 contains only coeliac disease status, model 2 contains coeliac disease status plus children’s demographic characteristics, model 3 contains model 2 plus children’s health characteristics, and model 4 contains model 3 plus parental characteristic. Ordinary least squares regression, $b$: unstandardised coefficients, $n=445\ 669$. *$p<0.05$; **$p<0.001$. 

In this analysis, the first model (model 1C) only included age at diagnosis of the disease; however, thereafter the models were built stepwise (models 2C–4C) as in the previous analyses. A statistically significant association was defined as having 95% CIs that did not include 0, corresponding to p<0.05. Statistics were calculated using SPSS V.24.0 2000.

Ethical consideration
This study was approved by the Research Ethics Committee of the Umeå University. Subject information was anonymised by Statistics Sweden prior to the analyses.

During this follow-up period, the mean age for completion of ninth grade was 16 years and the mean grade score for this population was 207 (SD=66). Additional basic descriptive statistics are shown in table 1.

Child characteristics and school performance
We found no significant association between coeliac disease and school performance at ninth grade (table 2). In these birth cohorts (1991–1994), girls performed better than boys at ninth grade. Using the 1991 birth cohort as a reference, a noticeable annual drop in grades was seen for later cohorts. Apgar score showed no significant association with school grades while being born small for gestational age appeared to negatively impact children’s performance. Notably, children with coeliac disease diagnosed at 13–15 years of age performed better in ninth grade compared with children diagnosed earlier in life; however, this relationship disappeared after adjusting for parental characteristics (table 3).

Parental characteristics and school performance
Living in a household with an unmarried/non-cohabiting parent was significantly associated with poorer performance at ninth grade compared with living in a household of married/cohabiting parents. Scores at ninth grade were also significantly associated with parental education and income; the higher the levels of parental education and income, the higher the grade scores on completion of the ninth grade. For all interaction terms included, we found no statistically significant association and thus these results are not shown.

Table 3 Impact of age at diagnosis of coeliac disease on school achievement at ninth grade completion, taking child and parental characteristics into account

<table>
<thead>
<tr>
<th>Child and parental characteristics</th>
<th>Model 1C</th>
<th>Model 2C</th>
<th>Model 3C</th>
<th>Model 4C</th>
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<td>Ref</td>
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<td>13–15</td>
<td>9.9*</td>
<td>1.8 to 18.1</td>
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<td>2.3 to 18.6</td>
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<tr>
<td>Sex</td>
<td>Male</td>
<td>Ref</td>
<td>Female</td>
<td>21.1**</td>
</tr>
<tr>
<td>Year of birth</td>
<td>1991</td>
<td>Ref</td>
<td>1992</td>
<td>–4.6</td>
</tr>
<tr>
<td>1993</td>
<td>5.5</td>
<td>–2.6 to 13.6</td>
<td>5.8</td>
<td>–2.5 to 14.1</td>
</tr>
<tr>
<td>1994</td>
<td>3.1</td>
<td>–6.3 to 12.5</td>
<td>2.8</td>
<td>–6.8 to 12.0</td>
</tr>
<tr>
<td>Apgar score at 5 min</td>
<td>7–10</td>
<td>Ref</td>
<td>&lt;7</td>
<td>11.2</td>
</tr>
<tr>
<td>Small for gestational age</td>
<td>No</td>
<td>Ref</td>
<td>Yes</td>
<td>–14.8</td>
</tr>
<tr>
<td>Family type</td>
<td>Married/cohabiting</td>
<td>Ref</td>
<td>Single</td>
<td>–22.4**</td>
</tr>
<tr>
<td>Mothers’ education</td>
<td>≤9 years schooling</td>
<td>Ref</td>
<td>Upper secondary</td>
<td>23.1**</td>
</tr>
<tr>
<td>University &lt;2 years</td>
<td>University ≥2 years</td>
<td>46.2**</td>
<td>27.8 to 61.2</td>
<td>45.3**</td>
</tr>
<tr>
<td>Mother’s income</td>
<td>Low</td>
<td>Ref</td>
<td>Middle</td>
<td>6.4</td>
</tr>
<tr>
<td>High</td>
<td>12.8*</td>
<td>6.2 to 20.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father’s education</td>
<td>≤9 years schooling</td>
<td>Ref</td>
<td>Upper secondary</td>
<td>15.1**</td>
</tr>
<tr>
<td>University &lt;2 years</td>
<td>University &gt;2 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father’s income</td>
<td>Low</td>
<td>Ref</td>
<td>Middle</td>
<td>8.6**</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Model 1C contains age at diagnosis, model 2C contains age at diagnosis plus children’s demographic characteristics, model 3C contains model 2 plus children’s health characteristics, and model 4C contains model 3 plus parental characteristics.

Ordinary least squares regression, b=unstandardised coefficients, n=1767.

*p<0.05; **p<0.001.
completion of the ninth grade. However, being small for gesta-
tional age, being born after 1991 and living in a single parent
household were all strongly associated with low performance. In
contrast, high performance at ninth grade was predicted by being
female and having parents with high education and income.

Coeliac disease and school performance
The absence of an association between coeliac disease and school
performance is probably due to early coeliac disease diagnosis
and adherence to a gluten-free diet. This study hypothesised that
celiac disease may affect school performance based on evidence
from earlier studies showing a link between coeliac disease and
cognitive performance. However, these earlier studies were
performed on adult populations, whereas cases in the present
study were diagnosed between 0 and 15 years of age. It may
be that the negative effect of coeliac disease is only evident
following long exposure to gluten such as in individuals with
a delayed diagnosis. Hu et al showed the impact of coeliac
disease on cognitive performance to be more pronounced in the
elderly.17 Similarly, Hadjivassiliou et al reported that the onset
of symptoms of cognitive dysfunction occurred on average at
53 years of age among patients with gluten ataxia.23 Casella et
al confirmed that poor cognitive performance was pronounced
in patients diagnosed with coeliac disease during adulthood.30
Additionally, it is plausible that our cases adhere to the recom-
manded strict gluten-free diet and thus are living a relatively
normal life following early diagnosis. Even though we did not
include data on nutrition, the earlier study from this population
reported an 82% gluten-free diet compliance rate.31 Interest-
ingly, age at diagnosis did not appear to play a significant role.
Children diagnosed after 13 years of age tended to perform
better. However, this could be due to a socioeconomic bias, as
this relationship disappeared when we controlled for resources,
that is, parental education and income.

Other child characteristics and school performance
The finding that children born small for gestational age
performed poorly at ninth grade compared with others is in line
with previous studies.32 The mechanism underlying pregnancy
length at birth and performance at ninth grade is likely to be
multifactorial; it has been suggested that preterm children have
an increased risk of delayed development, cognitive impair-
ments, learning disabilities, behavioural problems and emotional
problems, among other issues.33 These factors negatively impact
school performance. Our findings on decreasing school perform-
ance in birth cohorts over time and better performance among
girls are also in line with earlier studies.34 This study does not
explain why there is decrease in performance at ninth grade
in the recent years or as to why girls outperform boys, further
research is needed.

Parental conditions and school performance
We reported that school performance at ninth grade was posi-
tively associated with parental income and education. This
finding confirms a well-documented association between socio-
economic status and academic achievement.35 Parental income
reflects the economic and social resources available to the child,
and parental education was linked to both parental income and
levels of engagement in the child's education.36 Low perform-
ance was significantly higher in children living with non-mar-
rried/non-cohabiting parents, and similar observations have been
shown by earlier studies.37 This negative effect has previously
been attributed to detrimental stress arising from parental
conflict following divorce/separation, the meager economic
resources typical in most one-parent homes and time pressures
on single parents making them less able to participate in the
child’s schooling.37 38

CONCLUSION
In conclusion, coeliac disease diagnosed during childhood in
Sweden is not associated with poor school performance at ninth
grade.

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was developed with support from the Swedish Research Council and by strategic
global funding from Umeå University.

Contributors MS and KH were responsible for the conceptualisation of the study,
supervised the analysis process and offered quality control of both data and the final
study results. AP provided clinical insights and interpretation of the study variables
and the research findings. FN performed the statistical analyses and wrote the
manuscript. All authors contributed to the selection of the studied variables, choice
of study design, interpretation of study findings, and revision of the manuscript, and
have approved the submitted version of the manuscript.

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Competing interests None declared.

Ethics approval Swedish Ethical Review Board.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement All data for this study are available through the Umeå
SIMSAM Lab. More data similar to the one used in this study can be obtained from
Statistics Sweden and the Swedish National Board of Health and Welfare upon
request and ethical clearance.

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