

# BMJ Open Association of area-level education with the regional growth trajectories of rates of antibacterial dispensing to patients under 3 years in Norway: a longitudinal retrospective study

Sigbjørn Svalestuen <sup>1</sup>, Kristian Svendsen,<sup>2</sup> Anne Elise Eggen,<sup>3</sup> Lars Småbrekke<sup>2</sup>

**To cite:** Svalestuen S, Svendsen K, Eggen AE, *et al.* Association of area-level education with the regional growth trajectories of rates of antibacterial dispensing to patients under 3 years in Norway: a longitudinal retrospective study. *BMJ Open* 2022;**12**:e058491. doi:10.1136/bmjopen-2021-058491

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2021-058491>).

Received 19 October 2021  
Accepted 19 August 2022



© Author(s) (or their employer(s)) 2022. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

<sup>1</sup>Department of Social Science, UiT The Arctic University of Norway, Tromsø, Troms og Finnmark, Norway

<sup>2</sup>Department of Pharmacy, UiT The Arctic University of Norway, Tromsø, Troms og Finnmark, Norway

<sup>3</sup>Department of Community Medicine, UiT The Arctic University of Norway, Tromsø, Troms og Finnmark, Norway

## Correspondence to

Sigbjørn Svalestuen;  
[sigbjorn.svalestuen@uit.no](mailto:sigbjorn.svalestuen@uit.no)

## ABSTRACT

**Objective** To examine the association between area-level education and the local growth trajectories in antibacterial dispensing rates in Norwegian municipalities among children under 3 years old.

**Design** Retrospective, longitudinal study using individual primary care prescription data from the Norwegian Prescription Database for the period 2006–2016. Data were collected on the date of dispensing, the type and amount of antibiotic, the patient's age, sex and municipality of residence and linked to municipality-level statistics on education available from Statistics Norway. We used multilevel growth curve modelling, with a linear trend variable modelled as a random effect and a cross-level interaction between linear trends and the proportion of the population in the municipality having received a university or college education.

**Setting** The local government level in Norway. The sample includes all municipalities over the study period.

**Outcome measure** Number of dispensed antibacterial prescriptions per 100 children in individual primary care by municipality and year.

**Results** We identified a significant negative linear trend in the square root of the dispensing rate for children under 3 years old during the period. This trend varied between municipalities. A negative cross-level interaction term between population education levels and random trends showed that municipalities with an average level of population education saw a reduction in their square root dispensing rates of  $-0.053$  (95% CI  $-0.066$  to  $-0.039$ ) prescriptions per 100 children. Each additional percentage point in population education contributed a further  $-0.0034$  (95% CI  $-0.006$  to  $-0.001$ ) reduction to the square root dispensing rate.

**Conclusions** Municipalities in which a larger proportion of the local population have high educational achievements have been more successful in reducing antibacterial dispensing rates in children under 3 years old. Adopting area-level strategies and addressing local community disadvantages may help to optimise practices and prescribing patterns across local communities.

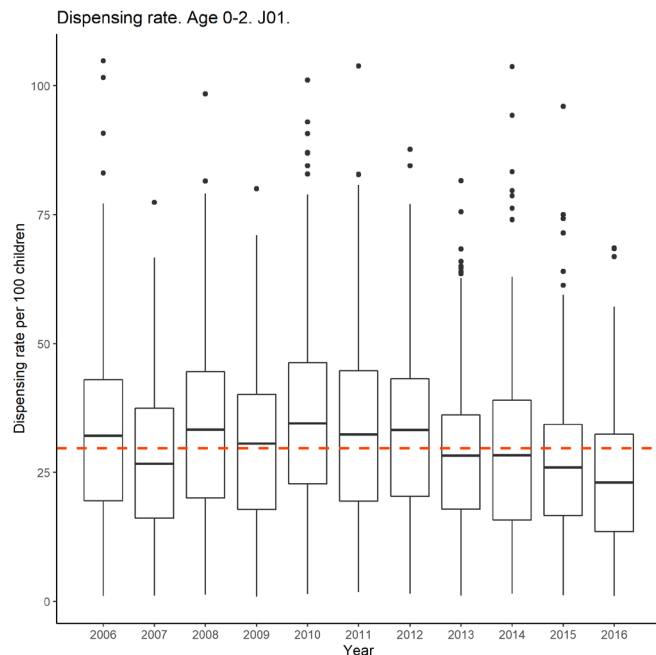
## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Complete antibacterial dispensing data allow estimations of local community dispensing rate trends and their associations with education at a high level of spatial resolution.
- ⇒ By including all Norwegian municipalities, we explored the total extent of local variations in dispensing rates under national reduction policy guidelines.
- ⇒ Aggregate data cannot directly infer individual-level decision-making and needs.
- ⇒ We were unable to control for the geographical burden of infectious disease in the age groups under examination.

## INTRODUCTION

The periodic prevalence and patterns of antibiotic use vary between countries<sup>1</sup> and between socioeconomic and demographic groups within countries,<sup>2–6</sup> and studies have also shown temporal variations in the dispensing of antibacterials for systemic use.<sup>7–8</sup> One study from Norway found an overall reduction in the number of dispensed prescriptions among children aged 0–2 between 2005 and 2016, with the prevalence varying between counties.<sup>9</sup> Another study found that, among Norwegian children aged 0–2, 1-year olds consistently had the highest antibacterial dispensing rates between 2008 and 2016.

Several studies have attributed variations in antibacterial use to socioeconomic characteristics,<sup>3–5 10–12</sup> often including an indexed area-level deprivation measurement to capture several dimensions of deprivation (eg, education, income, barriers to housing, crime, employment). Crowding, hygiene, lower host resistance due to poor nutrition, stress and smoking prevalence create a greater risk of infectious illness among people of lower socioeconomic status, but general practitioners'



**Figure 1** Box-and-Whisker plot of dispensing rates by year. The dashed line is the grand mean dispensing rate throughout the period. The main takeaway from this figure is the notable variation between municipalities within a specific year. The intraclass correlation coefficient of the null model indicates that 62.8% of the total variance is between municipalities.

treatment practices and their interactions with family attitudes towards demanding certain treatments may influence prescription dispensing,<sup>2 13</sup> resulting in geographic and temporal variations in aggregate statistics. Education is associated with the awareness and proper use of antibacterials<sup>14–16</sup> and with the individual capacity to obtain, process and understand health information,<sup>17 18</sup> and cultural factors, such as individual versus collective value systems, and future-oriented behaviour have also been associated with prescription patterns at multiple levels.<sup>19</sup>

Studies on variations in dispensed antibiotics in Norway have not explicitly modelled local variations in dispensing rate growth trajectories in terms of socioeconomic composition. The aim of this study was to investigate the association between population education levels and growth trajectories in antibacterial dispensing rates at the municipality level using longitudinal data and a multilevel growth curve model.

## MATERIALS AND METHODS

The Norwegian Prescription Registry (NorPD) contains all prescriptions with a valid unique personal identifier redeemed at Norwegian pharmacies; details of the NorPD are published elsewhere.<sup>20</sup> We considered the period from 2006 to 2016 and included 734 359 prescriptions. We aggregated prescriptions if the same individual received two or more prescriptions for the same antibacterial drug on the same date, and we excluded records for individuals aged more than 1095 days (3 years) and

those who died during the observation period. We used the following data from the NorPD: sex; year and month of birth; unique personal identifier; municipality of residence; date on which the prescription was dispensed at the pharmacy and the Anatomical Therapeutic Chemical Classification System (ATC) code at the fifth level. As we only had information on the birth month in our data, we assigned a fictitious birth date of the 15th of the birth month and calculated age as the date of dispensing minus this date.

Data in NorPD are pseudonymised, allowing longitudinal observation of an individual who is anonymous to the researcher. Individual data were aggregated at the municipality level, and dispensing rates were calculated as the yearly number of prescriptions within a municipality per 100 children. We linked the aggregated prescription data to publicly available data on all Norwegian municipalities using the unique municipality identification number system. Analyses were restricted to ATC J01: antibacterials for systemic use.<sup>21</sup> The data cover the entirety of Norway at the local administrative level. Figure 1 presents a box-and-whiskers plot of the calculated local dispensing rate by year. Online supplemental appendix figure A1 presents a sample of trends and intercepts fitted to the dispensing rate metric.

## Exposure and covariates

Our exposure was the proportion of the population in a municipality who had received tertiary education (university level for 3 or more years).<sup>22</sup> We chose tertiary education as our education indicator for two reasons. First, the literature states that knowledge of the proper use of antibiotics is more common among people who have received a higher education,<sup>14–16</sup> and second, the Norwegian education system ensures all young people the legal right to education up to and including upper secondary education, but no such right exists for higher education. Thus, continued education past the secondary level is an active choice, in contrast to structured schooling, so we would expect local population diversity.

We included a covariate for the proportion of the population in a municipality living in a household with less than 60% of the national median income,<sup>23</sup> which is the standard definition of low income in the European Union. The association between deprivation and dispensing rates<sup>3–5</sup> suggests that poverty may confound the relationship between dispensing rates and population education, and including this covariate served to partial out effects that could be attributed to education rather than to material deprivation.

The municipality population size may be related to levels of regional deprivation in education and to regional development and may, therefore, impact access to health-care services. A previous study identified an association between municipality population size and dispensing rates in Norway,<sup>6</sup> and municipality size is, therefore, likely to confound the link between education and dispensing rates. Populations of Norwegian municipalities vary from

fewer than 400 to more than 600 000 residents, and to best capture this variance, we calculated the natural logarithm of population size collected from official statistics<sup>24</sup> as an indicator of municipality size.

Finally, we included an indicator for the median travel time to the nearest pharmacy, calculated using Google Maps to determine travel time between all addresses in Norway and their three nearest straight-line pharmacies, selecting the shortest travel time by car for each address before aggregating to the municipality level. A previous Norwegian study<sup>25</sup> found a link between dispensing rates and travel times to pharmacies in Norway. If education levels are geographically determined, they are also likely to correlate with pharmacy access, and it is, thus, important to partial out the effects of ease-of-pharmacy access from the educational coefficients.

### Statistical analysis

Multilevel growth curve models are a special case of multilevel models in which a coefficient of time varies between units.<sup>26</sup> The variation in each unit of the dispensing rate is modelled as a fixed growth trajectory plus a random error term, which means that the parameters of growth can be modelled by background characteristics.<sup>27</sup> Applying this to our data, the municipalities are repeatedly observed, such that level 1 constitutes the longitudinal part of the model and level 2 captures the variance between the municipalities.

We centred all level 1 covariates, except time, on their cluster means—that is, centring within cluster—to achieve orthogonality between the level 1 and level 2 variables.<sup>28</sup> The covariates at level 1 were annual measurements of poverty, education and municipality population size, which reflect changes in the municipality by year. The same covariates were aggregated at level 2 as cluster means. These covariates reflect differences between municipalities over the period under study. All level 2 covariates were conversely centred on their grand mean. This centring scheme allows for easier interpretation of main effects in the interaction term, in which the estimated trend coefficient is interpreted as the expected mean dispensing rate trend in municipalities at average levels of population education. Time (L1) was not centred because we were interested in the average trend over the period (see Biesanz *et al*<sup>29</sup> for a discussion on centring time in growth curve models).

The multilevel growth curve model assumes that time-variant covariates are not characterised by a systematic growth process, and the inclusion of simultaneous growth processes in a multilevel growth curve model may lead to misspecification and biased effects.<sup>30</sup> Within-municipality variations in education levels are highly correlated with time ( $r = .95$ ), providing evidence for simultaneous growth and biasing the trend coefficient. We, therefore, removed the time-variant education predictor, as our goal was to estimate a cross-level interaction effect between the time-invariant education predictor and trends. We detail this choice further in the online supplemental appendix

and demonstrate the consequences of simultaneous growth on trend estimation in online supplemental table A1.

We performed a square root transformation on the dispense rate metric to improve the model fit, but the coefficients on the square root scale lack the clean interpretability of coefficients on the original scale. We, therefore, used the square root model for predictions and for the evaluation of statistical significance but present the predicted dispensing rates using the original scale to aid in interpretation. Untransformed and square root transformed dispensing rate distributions are available in online supplemental appendix figure A2 and A3, respectively.

The model fit was assessed using the Akaike information criterion, the Bayesian information criterion and residual diagnostic plots. Residual diagnostic plots are available in online supplemental appendix figure A4–A7. All models were estimated using the R package *nlme*, incorporating a compound symmetric error covariance structure to deal with within-group autocorrelation. A model equation and a parameter description are available in the online supplemental appendix.

### Patient and public involvement

No patients were involved.

### RESULTS

The model results are shown in table 1, and figures 2 and 3 are based on estimates from the model. An untransformed version of the model is available in online supplemental table A2. Table 2 shows summary statistics for the types of antibacterial in the database, together with the total number of defined daily doses dispensed, summarised by year and subgroup. Table 3 presents summary statistics. Online supplemental table A3 includes detailed summary statistics on within and between components specifically.

From model 1 in table 1, it can be seen that the estimated mean trend of the square root dispensing rate at mean levels of population education is equal to  $-0.053$  ( $SD=0.0927$ ,  $p<0.001$ ). A one percentage point increase in cluster mean education reduces the trend coefficient of the square root dispensing rate by  $-0.0034$  ( $p=0.0051$ ), *ceteris paribus*. There is, thus, a greater reduction in the dispensing rate in municipalities in which a larger proportion of the population has received tertiary education.

Figure 2 presents the predicted trajectories in the dispensing rates based on cluster mean education levels. An important observation is that the trends are, on average, negative within the boundaries of the data. Even the municipalities with the lowest levels of population education (11%) show predicted reductions in dispensing rates. The predictions fan out from similar intercepts due to the small and insignificant ‘main’ effect of education (the effect when  $T = 0$ ,  $p=0.892$ ) in the model. The figure shows that the municipalities with low levels of population education have predicted reductions

**Table 1** Multilevel linear growth curve model

Coefficient	$\sqrt{\text{Dispensed Rx per 100 children}}$	P values
Level 1		
Trend	-0.053 (-0.066 to -0.039)	<0.001
Poverty	-0.098 (-0.125 to -0.070)	<0.001
Population (ln)	1.265 (-0.061 to 2.592)	0.062
Level 2		
Education	-0.002 (-0.027 to 0.023)	0.892
Population (ln)	0.408 (0.290 to 0.525)	< 0.001
Poverty	-0.085 (-0.130 to -0.041)	< 0.001
Travel	-0.0003 (-0.0004 to -0.0003)	< 0.001
Trend×Education (L2)	-0.0034 (-0.006 to -0.001)	0.005
Intercept	5.459 (5.340 to 5.578)	< 0.001
Variance components		
Standard deviation. $\mu_1$	.0927	
Standard deviation $\mu_0$	.8647	
Misc.		
$\rho$ Compound symmetry	.000	
Groups	426	
Observations	4503	
Log Likelihood	-6442.764	
Akaike information criterion	12913.53	
Bayesian information criterion	13003.3	

95% CI in parentheses.

The model uses the square root of the transformed dispensing rates as outcomes. This model is used for the prediction (figures 2 and 3) and evaluation of statistical significance and rates of change. Complete information is missing only for two municipalities due to municipality mergers during the period.

of approximately two prescriptions per 100 children, while municipalities with comparatively high levels of population education have predicted reductions approximately equal to 10 prescriptions per 100 children over the period. In [figure 3](#), several municipalities can be seen to have a positive-predicted trend after adjusting for the interaction with education. Most municipalities, however, show a predicted negative trend in the cross-level interaction model, and the size of the negative trend varies with population education in the municipality.

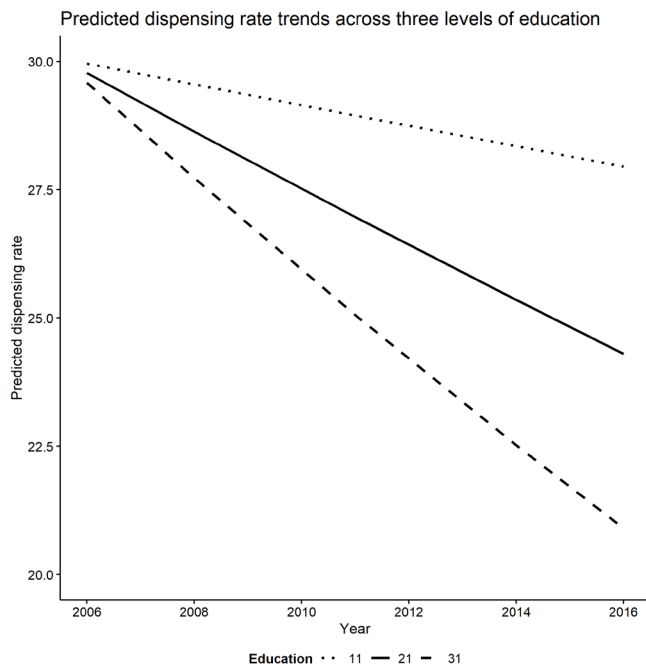
## DISCUSSION

While there has been a national decrease in antibacterial dispensing rates in Norway,<sup>31</sup> the current study shows that trends vary between Norwegian municipalities for patients below 3 years of age, with municipalities in which more of the population has received tertiary education showing larger decreases in dispensing rates. Several efforts have been made to reduce antibacterial dispensing rates, notably by updating national guidelines for the use of antibacterials<sup>32</sup> and through intervention campaigns.<sup>33</sup> If one views high education levels as a form of socioeconomic advantage, the results suggest that

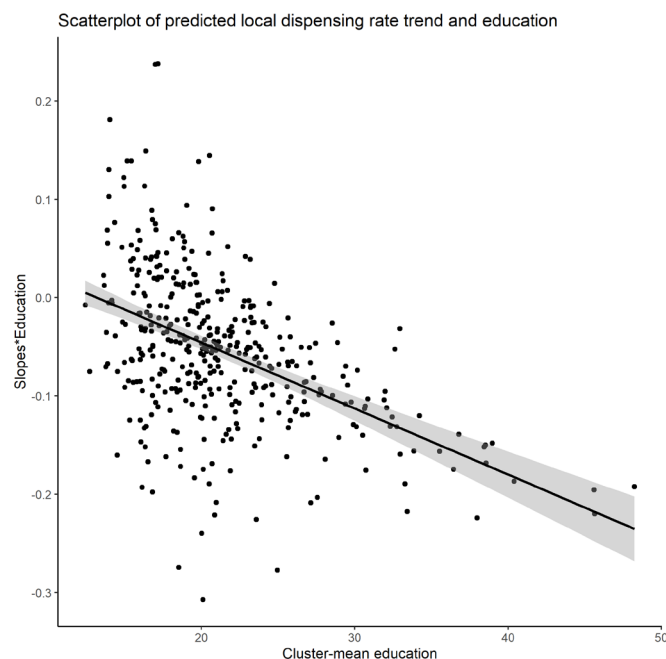
municipalities with socioeconomically advantaged populations have been more successful in reducing dispensing rates.

Our findings support the existing literature on the relationship between relative socioeconomic deprivation and antibacterial dispensing rates. Low parental education has been linked to higher prescribing rates in paediatric patients,<sup>2 5 13 34</sup> and we would expect the same individual mechanisms to translate to aggregate statistics. If a lack of higher education in a community is considered a form of regional deprivation, then these results are consistent with other data on the association between area-level deprivation indexes (which include education in the index) and dispensing rates.<sup>3 4 11</sup>

We chose tertiary education as our education indicator because proper use of antibiotics is more common in people who have received higher education,<sup>14–16</sup> and our findings are consistent with these expectations. In addition, the Norwegian education system ensures all young people the legal right to education up to and including the upper secondary level, but no such right exists for higher education. Thus, continued education past secondary level is an active choice in which we would



**Figure 2** Predicted cross-level interaction effect between trends and education. The Y-axis displays the dispensing rate on the original scale. The middle line represents the average cluster level of education, while the outer lines are predicted trends for  $\pm 2$  SD from the mean education levels. Predictions fan out from similar intercepts due to the insignificant main effect of education (effect when  $T=0$ ).



**Figure 3** Predicted slopes by population education. The points are the predicted square roots of the dispensing rate trends for each municipality. All 426 estimated trends are presented and plotted against education on the X-axis. The figure shows that the leaders in dispensing rate reductions also tend to have higher proportions of people with tertiary education and, conversely, that low performers tend to have lower levels of tertiary education. Please note the Y-axis scaling when interpreting the figures.

expect local population diversity, in contrast to structured schooling.

Health literacy is also associated with higher education,<sup>17 18</sup> but education is an inaccurate proxy for individual health literacy.<sup>35</sup> However, the overuse of antibacterials and policies implemented to reduce consumption are not only an issue of individual health but also of public health. Successful enactment of public health policies directed at reducing antibacterial dispensing rates may rely in part on the ability of individuals and groups to obtain, process, understand, evaluate and act on information needed to make decisions that benefit the individual and the community,<sup>36</sup> allowing collectivist and long-term values to outweigh individualist short-term decision-making. It is possible that education enables an understanding of the individual and family as being embedded in society, such that individual decisions on antibacterial treatment are more likely to be made within the framework of a greater public health concern.

The Norwegian healthcare system provides universal healthcare access, and health inequalities in care utilisation have diminished over time.<sup>37</sup> Need-adjusted socioeconomic differentiation in healthcare usage has empirically been observed mostly in the use of private medical specialists and hospital outpatient care.<sup>38</sup> However, these observations do not necessarily include all differentiation in healthcare usage in Norway, such as potential geographic variations, and, importantly, these studies do not include parental healthcare seeking. If parental healthcare seeking translates to paediatric healthcare seeking, healthcare usage may, hypothetically, not be socially determined in volume, but rather in kind. People from advantaged socioeconomic backgrounds may interact and use healthcare inputs more efficiently, thus achieving the same amount of health investment with less healthcare services. They may also consider the potential consequences of antibacterial use more frequently, driving the dispensing rate downward.<sup>5</sup>

Importantly, children are themselves not actors in this framework. Decisions on treatment are made by physicians and parents, which suggests that the healthcare provided to children is dependent on parental socioeconomic status and how they seek healthcare for their children as well as the physician's prescribing habits and responses to different individuals and social groups. Several studies have identified an association between the high use of antibacterials in young children and an increased risk of chronic disease development later in life,<sup>31 39–43</sup> so optimising prescribing practices would seem important for reducing health inequalities in future generations.

Area-level strategies, as opposed to national-level strategies, for antimicrobial stewardship have been suggested in other countries<sup>10</sup>; given the local and regional variations in dispensing rates and reduction trends in Norway, we agree with previous authors<sup>19</sup> that effective antimicrobial stewardship requires that the issue be addressed from a multilevel systems perspective and that social, structural and cultural determinants also be considered

**Table 2** Total dispensed DDD per 1000 children by ATC J01 subgroups

Year	J01A	J01C	J01D	J01E	J01F	J01G	J01M	J01X
2006	0.4	1009.1	19.9	77.9	526.2	7.6	1.0	17.4
2007	0.3	923.1	16.3	58.2	453.9	2.9	1.0	11.9
2008	0.2	1158.4	19.8	73.6	504.3	9.2	0.9	13.0
2009	0.2	1057.2	18.4	69.5	418.3	6.9	0.5	10.1
2010	0.2	1296.7	22.5	74.6	502.5	0.7	0.8	9.8
2011	0.1	1170.5	21.7	70.1	566.4	2.7	1.3	8.0
2012	0.4	1195.9	17.0	68.1	484.1	1.1	1.3	7.3
2013	0.4	1001.6	20.9	66.7	355.6	0.9	2.0	5.6
2014		1104.1	24.2	71.2	367.3	1.3	1.6	7.4
2015	0.1	965.6	21.8	67.1	299.9	0.9	1.3	8.7
2016	0.0	911.2	20.1	58.3	260.8	2.0	1.8	5.2

DDD, defined daily dose; J01A, tetracyclines; J01C, beta-lactam antibacterials, penicillins; J01D, other beta-lactam antibacterials; J01E, sulfonamides and trimethoprim; J01F, macrolides, lincosamides and streptogramins; J01G, aminoglycoside antibacterials; J01M, quinolone antibacterials; J01X, other antibacterials.

when implementing policy at the local administrative level. The overall responsibility for health policies in Norway lies with the National Ministry of Health, and stewardship of antimicrobial resistance in Norway relies on existing administrative structures of disease prevention and control, with sectoral operative responsibility and weak coordination mechanisms.<sup>44</sup> National political strategies do target primary healthcare services at the municipal level, but the need for and potential drivers of antibacterial treatment may vary between municipalities. We expect the efficacy of national policies for reducing antibacterial dispensing rates to partially depend on the local population's socioeconomic composition.

### Strengths, limitations and methodological considerations

Unlike several authors who have applied indexed deprivation measures containing a variety of deprivation indicators, we focused on education specifically because it is a common component of deprivation indexes, which present a trade-off between interpretation and capturing a holistic concept of deprivation. It is, thus, unclear

which features of such deprivation indexes drive empirical variations in dispensing rates, and translating theoretical mechanisms from the individual level to aggregate statistics then becomes even more challenging due to the number of dimensions in such indexes. The effects of income and occupation deprivation have been studied separately,<sup>4</sup> but no such analysis has been performed using an education indicator. Education is a key socioeconomic characteristic for health determinants, and by investigating education specifically, our results are more readily interpreted and more clearly relatable to the specific mechanisms discussed in the literature.

A strength of this study is the completeness of the dispensing rate metric. The NorPD contains all prescriptions dispensed in the period under examination, excluding usage in hospitals. We argue that this has two advantages. First, we expect education to matter more in the context of primary healthcare, because parents are active participants in healthcare decision-making, and second, the primary healthcare service is administered at the municipal level in Norway. Observed trends are, therefore, likely to be a result of local community needs and behaviours and local decision-making processes.

A limitation of this study is the lack of information on the geographical burden of disease, although regional differences in dispensing rates are unlikely to be explained by differences in the severity and density of infections and more likely to be related to differences in medical practices.<sup>9</sup> A Welsh study similarly found no support for regional differences in prescriptions being explainable by chronic conditions in the adult population.<sup>3</sup> Indeed, if the entire variance could be explained by the burden of infections, the implication would be that infections requiring antibacterial treatment are geographically unequally distributed, even between paediatric patients.

Another limitation is the limited inferences that can be made regarding individual outcomes based on aggregate

**Table 3** Pooled statistics, including summary statistics for yearly observations for all municipalities, before centring

Statistic	N	Mean	Standard deviation	Minimum	Maximum
Dispensed Rx/100 children	4519	29.7	16.3	0.9	104.9
Education	4515	21.2	5.9	9.1	51.9
Population	4519	11 885	35 479	200	658 390
Poverty	4518	10.0	2.4	3.7	21.8
Trend	4519	5.01	3.16	0	10
Travel time (sec)	426	1674	1882	182	13 129

The variable Dispensed Rx/100 child is the dependent variable used in the model. Travel time is presented in decimal minutes and is time-invariant due to only being observed once. An extended table of summary statistics, including both centred and non-centred values, is available in the online supplemental appendix.

statistics. Further research is necessary to conclude an association between parental education, individual interactions with healthcare services and paediatric antibacterial dispensing rates in Norway.

## CONCLUSION

Our analysis shows that the ability to reduce dispensing rates over time at the municipality level is associated with mean population levels of higher education. Local needs and potential root causes of health outcomes should be considered in antimicrobial stewardship to optimise prescription patterns, and attention should be paid to social demographics, like education, that may affect health behaviour, preferences and usage, which may help to further reduce dispensing rates in accordance with political goals.

**Contributors** SS conceptualised, designed and drafted the manuscript; prepared data; and performed the statistical analysis. KS contributed data. LS provided ethics approval and data from the prescription registry. SS, KS, AEE, and LS critically revised the manuscript. SS acts as the guarantor. All authors read and approved the final manuscript.

**Funding** The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient and public involvement** Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Not applicable.

**Ethics approval** This study involves human participants but Regional Committees for Medical and Health Research Ethics Norway (2018/1021) exempted this study. Exempt from informed consent under the Norwegian Health Research Act. Data on prescriptions are retrospective and routinely collected through a national registry (making informed consent difficult), and the project was deemed valuable for the public. Individual prescription information was only used to calculate municipality dispensing rates and volume. The only information used relating to individual patients were their municipality of residence.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available upon reasonable request. Data may be obtained from a third party and are not publicly available. Data on antibacterial dispensing can be obtained by application to a third party (The Norwegian Prescription Registry) and are not publicly available. Travel time data are available from the corresponding author upon request. Data collected from Statistics Norway are licensed under the Creative Commons Attribution 4.0 International (<https://www.ssb.no/en/diverse/lisens>) and are available from the corresponding author upon request.

**Supplemental material** This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

**Open access** This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

## ORCID iD

Sigbjørn Svaldstuen <http://orcid.org/0000-0002-4775-311X>

## REFERENCES

- 1 Van Boeckel TP, Gandra S, Ashok A, *et al*. Global antibiotic consumption 2000 to 2010: an analysis of national pharmaceutical sales data. *Lancet Infect Dis* 2014;14:742–50.
- 2 Thrane N, Olesen C, Schönheyder HC, *et al*. Socioeconomic factors and prescription of antibiotics in 0- to 2-year-old Danish children. *J Antimicrob Chemother* 2003;51:683–9.
- 3 Adekanmbi V, Jones H, Farewell D, *et al*. Antibiotic use and deprivation: an analysis of Welsh primary care antibiotic prescribing data by socioeconomic status. *J Antimicrob Chemother* 2020;75:2363–71.
- 4 Koller D, Hoffmann F, Maier W, *et al*. Variation in antibiotic prescriptions: is area deprivation an explanation? analysis of 1.2 million children in Germany. *Infection* 2013;41:121–7.
- 5 Filippini M, Masiero G, Moschetti K. Socioeconomic determinants of regional differences in outpatient antibiotic consumption: evidence from Switzerland. *Health Policy* 2006;78:77–92.
- 6 Haugen P, Simonsen GS, Primicerio R, *et al*. Antibiotics to outpatients in Norway—Assessing effect of latitude and municipality population size using quantile regression in a cross-sectional study. *Pharm Stat* 2018;17:4–11.
- 7 Sakshaug S, Strøm H, Berg C. *Legemiddelforbruket i Norge 2013–2017. Legemiddelstatistikk 2018: 1 [Drug consumption in Norway 2013–2017. Drug statistics 2018: 1*. Oslo: Norwegian Institute of Public Health, 2018.
- 8 Blix HS, Engeland A, Litlekare I, *et al*. Age- and gender-specific antibacterial prescribing in Norway. *J Antimicrob Chemother* 2007;59:971–6.
- 9 Stordal K, Marild K, Blix HS. Bruk AV antibiotika HOS barn I perioden 2005–16. *Tidsskr Nor Laegeforen* 2017;137:1414–20.
- 10 Mölter A, Belmonte M, Palin V, *et al*. Antibiotic prescribing patterns in general medical practices in England: does area matter? *Health Place* 2018;53:10–16.
- 11 Thomson K, Berry R, Robinson T, *et al*. An examination of trends in antibiotic prescribing in primary care and the association with area-level deprivation in England. *BMC Public Health* 2020;20:1–9.
- 12 Hobbs MR, Grant CC, Ritchie SR, *et al*. Antibiotic consumption by New Zealand children: exposure is near universal by the age of 5 years. *J Antimicrob Chemother* 2017;72:1832–40.
- 13 Pichichero ME. Understanding antibiotic overuse for respiratory tract infections in children. *Pediatrics* 1999;104:1384–8.
- 14 Waaseth M, Adan A, Røen IL, *et al*. Knowledge of antibiotics and antibiotic resistance among Norwegian pharmacy customers – a cross-sectional study. *BMC Public Health* 2019;19:1–2.
- 15 Agarwal S, Yewale VN, Dharmapalan D. Antibiotics use and misuse in children: a knowledge, attitude and practice survey of parents in India. *J Clin Diagn Res* 2015;9:SC21.
- 16 Yu M, Zhao G, Stålsby Lundborg C, *et al*. Knowledge, attitudes, and practices of parents in rural China on the use of antibiotics in children: a cross-sectional study. *BMC Infect Dis* 2014;14:1–8.
- 17 Dunn-Navarra A-M, Stockwell MS, Meyer D, *et al*. Parental health literacy, knowledge and beliefs regarding upper respiratory infections (URI) in an urban Latino immigrant population. *J Urban Health* 2012;89:848–60.
- 18 Sørensen K, Pelikan JM, Röthlin F, *et al*. Health literacy in Europe: comparative results of the European health literacy survey (HLS-EU). *Eur J Public Health* 2015;25:1053–8.
- 19 Blaser MJ, Melby MK, Lock M, *et al*. Accounting for variation in and overuse of antibiotics among humans. *Bioessays* 2021;43:e2000163:2000163.
- 20 Furu K. Establishment of the nationwide Norwegian prescription database (NorPD)—new opportunities for research in pharmacoepidemiology in Norway. *Nor Epidemiol* 2008;18:129–36.
- 21 WHO Collaborating Centre for Drug Statistics Methodology. ATC/DDD index, 2019. Available: [https://www.whocc.no/atc\\_ddd\\_index](https://www.whocc.no/atc_ddd_index) [Accessed Apr 2022].
- 22 Norway S. Educational attainment of the population, source table 09429: educational attainment, by municipality and sex (M), 1970–2020. Available: <https://www.ssb.no/en/statbank/table/09429/> [Accessed Apr 2022].
- 23 Statistics Norway. Income and wealth statistics for households, source table: 06947: persons in private households with annual after-tax income per consumption unit, below different distances to the median income. EU-scale and OECD-scale (M) (UD) 2005–2020. Available: <https://www.ssb.no/en/statbank/table/06947> [Accessed Apr 2022].
- 24 Norway S. Population count, source table 07459: population, by sex and one-year age groups (M) 1986–2022. Available: <https://www.ssb.no/en/statbank/table/07459> [Accessed Apr 2022].



- 25 Svendsen K, Kongsgard H, Haugen P. Travel time to pharmacy influence the use of antibiotics in Norway. *Pharmacoepidemiol Drug Saf* 2016;25:641.
- 26 Rabe-Hesketh S, Skrondal A. *Multilevel and longitudinal modeling using Stata*. College Station, TX: Stata Press, 2008.
- 27 Raudenbush SW, Bryk AS. *Hierarchical linear models: Applications and data analysis methods*. Thousand Oaks, CA: Sage, 2002.
- 28 Enders CK, Tofighi D. Centering predictor variables in cross-sectional multilevel models: a new look at an old issue. *Psychol Methods* 2007;12:121–38.
- 29 Biesanz JC, Deeb-Sossa N, Papadakis AA, et al. The role of coding time in estimating and interpreting growth curve models. *Psychol Methods* 2004;9:30–52.
- 30 Curran PJ, Obeidat K, Losardo D. Twelve frequently asked questions about growth curve modeling. *J Cogn Dev* 2010;11:121–36.
- 31 Beckström S, Svendsen K, Småbrekke L. Antibacterial use by birth year and birth season in children 0–2 years in Norway. *Nor Epidemiol* 2021;29:35–43.
- 32 Eliassen KE, Fetveit A, Hjortdahl P, et al. [New guidelines for antibiotic use in primary health care]. *Tidsskr Nor Laegeforen* 2008;128:2330–4.
- 33 Ministry of Health. *Handlingsplan mot antibiotikaresistens i helsetjenesten*, 2016.
- 34 Mangrio E, Wremp A, Moghaddassi M, et al. Antibiotic use among 8-month-old children in Malmö, Sweden--in relation to child characteristics and parental sociodemographic, psychosocial and lifestyle factors. *BMC Pediatr* 2009;9:31.
- 35 Berkman ND, Davis TC, McCormack L. Health literacy: what is it? *J Health Commun* 2010;15 Suppl 2:9–19.
- 36 Freedman DA, Bess KD, Tucker HA, et al. Public health literacy defined. *Am J Prev Med* 2009;36:446–51.
- 37 Vikum E, Bjørngaard JH, Westin S, et al. Socio-Economic inequalities in Norwegian health care utilization over 3 decades: the HUNT study. *Eur J Public Health* 2013;23:1003–10.
- 38 Vikum E, Krokstad S, Westin S. Socioeconomic inequalities in health care utilisation in Norway: the population-based HUNT3 survey. *Int J Equity Health* 2012;11:48–9.
- 39 Korpela K, de Vos WM. Antibiotic use in childhood alters the gut microbiota and predisposes to overweight. *Microb Cell* 2016;3:296–8.
- 40 Mårild K, Ye W, Lebwohl B, et al. Antibiotic exposure and the development of coeliac disease: a nationwide case-control study. *BMC Gastroenterol* 2013;13:1–9.
- 41 Risnes KR, Belanger K, Murk W, et al. Antibiotic exposure by 6 months and asthma and allergy at 6 years: findings in a cohort of 1,401 US children. *Am J Epidemiol* 2011;173:310–8.
- 42 Dydensborg Sander S, Nybo Andersen A-M, Murray JA, et al. Association between antibiotics in the first year of life and celiac disease. *Gastroenterology* 2019;156:2217–29.
- 43 Blaser MJ. Antibiotic use and its consequences for the normal microbiome. *Science* 2016;352:544–5.
- 44 Time MS, Veggeland F. Adapting to a global health challenge: managing antimicrobial resistance in the Nordics. *PaG* 2020;8:53–64.