

Epidemiology

Head lice predictors and infestation dynamics among primary school children in Norway

Tone Birkemoe^a, Heidi Heggen Lindstedt^b, Preben Ottesen^b, Arnulf Soleng^b, Øyvind Næss^{c,d} and Bjørn Arne Rukke^{b,*}

^aDepartment of Ecology and Natural resource management, Norwegian University of Life Sciences, PO Box 5003, NO 1432 ÅS, ^bDepartment of Pest Control, Norwegian Institute of Public Health, ^cDivision of Epidemiology, Norwegian Institute of Public Health and ^dInstitute of Health and Society, University of Oslo, Oslo, Norway.

*Correspondence to Bjørn Arne Rukke, Department of Pest Control, Norwegian Institute of Public Health, PO Box 4404, Nydalen, 0403 Oslo, Norway; E-mail: bjorn.arne.rukke@fhi.no

Abstract

Background. Health providers need to know which measures to take and children to prioritize in order to decrease costs associated with head lice infestations.

Objective. Our aim was to determine the most important predictors for head lice and identify the major drivers of an infestation outbreak in a low-prevalence area.

Methods. The study was based on three datasets of head lice prevalence (retrospective, point prevalence and prospective approach) from primary school children (ages 6–12) at 12 schools in Oslo, Norway. The tested predictors were siblings with lice, individual and household characteristics as well as class and school affiliation. Self-reported monthly incidences (prospective approach) of head lice were used to evaluate infestation dynamics.

Results. Infested siblings strongly increased the odds of head lice infestation of school children (odds ratio 36, 26 and 7 in the three datasets) whereas having short hair halved the odds. Household characteristics were of minor importance, and class affiliation proved more important than school affiliation. Having head lice in one school term increased the odds of an infestation in the next, but this effect diminished over time. About 97% of all self-reported infestations were noted in two consecutive months or less.

Conclusions. With the exception of hair length, we have found that individual and household characteristics are of minor importance to predict head lice infestations in a low-prevalence country and that unnoticed transmissions in school classes and families are likely to be the major driver upon outbreaks.

Key words. Multilevel analysis, pediculosis, population dynamics, prevalence, schools, socio-economic factors.

Introduction

Head lice (*Pediculus capitis* De Geer) have a worldwide distribution (1), and prevalence is generally higher among children than adults (2,3). Infestations can create psychological distress (4), and keeping children at home from school adds further substantial costs for households (5,6). Pediculosis also consumes considerable resources from public health authorities in developed countries through counselling and support to schools and families (3,6,7). To decrease these

costs, increased public knowledge (6) and information about head lice dynamics as well as individual and household risk factors are among the crucial elements that need to be elucidated. At present, our understanding is diverging and incomplete.

Head lice transmission primarily depends on number and intensity of head-to-head contacts (8,9) and is often considered to be highest within households. Increased head lice prevalence with number of household members (10) and in particular with number of children

(3) supports this assumption. Mossong *et al.* (11) found that contact rates were highest among 5–19-year-old individuals in Europe. Thus, potential infestation events may also be high among fellow classmates and schoolchildren. To determine the individual predictors of head lice, dependencies among siblings, class and schoolmates should therefore be included in statistical models together with individual (e.g. sex, hair length and colour) and household characteristics that are more traditionally investigated as predictors of head lice infestations (10,12–14). This use of mixed modelling has generally not been acknowledged in head lice research as only a few authors (10,13) have combined class and school affiliation with individual and household variables. To our knowledge, models estimating individual head lice predictors have not previously included the importance of infested siblings.

Head lice infestations are considered to be dynamic (15), which is a challenge for detecting risk factors. If partly treated or untreated infestations are common, these are likely to represent a core of children with head lice that should be detectable at several points in time. If, however, most children are successfully treated upon infestation as claimed earlier by Rukke *et al.* (5,6) in Norway, head lice infestations will move constantly between social contacts, probably diminishing the influence of individual or household risk factors. These two scenarios also call for different public health actions: help to families with treatment difficulties, as has been an important part of the British Bug-Busting Program (16), or focus on frequent and synchronized checking routines followed by synchronized treatment, as has been the major focus so far in Norway (5,6). In either case, the average duration of an outbreak is of importance to know how long the school or health providers should urge children with close social contact to more closely monitor their head lice status.

The overall aim of the present study was to investigate individual and household predictors of head lice in Oslo, Norway, taking dependencies within family, class and school into account. The dynamics of infestations is explored to understand the duration and major drivers in outbreaks. To increase the generality of the results and include several measures over time, we combined three approaches: screening and retrospective and prospective reports. The knowledge gained can be used directly in public health guidelines and strategies for head lice prevention.

Methods

Population and sampling

Primary school children (grades 1–7, ages 6–12) were recruited through 12 schools selected to span the geographic and socio-economic regions in Oslo (Mogstad M. Statistics Norway 2005). An invitation to participate was sent to all schools in Oslo, which had 300 children or more. Among the participating schools, the Inner East part of Oslo was represented by one school, but the other four regions (Old Suburbs, New Suburbs and Inner and Outer West) were represented by two schools or more. We based our data collection on three approaches: (i) self-reported history (retrospective approach), (ii) screening at schools and (iii) self-reported monthly incidences of head lice during 2 years (prospective approach). The schools had an average size of 472 students (range 337–615).

Retrospective reported history of head lice

A questionnaire was distributed to the children when they were screened for head lice in September 2008. It was to be filled out by their carers and returned to the school. The questions were answered by predefined categories and gave information about previous experience with head lice.

Screening for head lice

Children were dry combed for ~5 minutes using the Licesnatcher™, a comb mounted on a vacuum cleaner (<http://www.licesnatcher.co.uk/>). A filter collected all vacuumed head lice and was subsequently checked in a stereomicroscope by the staff at the Norwegian Institute for Public Health. All children at one school were screened the same day, and four schools were screened per week. Individual hair characteristics were noted at screening. The screening was carried out in September 2008. In Norway, sales of pediculicides are known to be highest at this time of the year (17).

All children with positive sightings of head lice were given a notice to their carers and an encouragement to treat the infestation. These children were reinspected for lice ~1 month later to investigate their treatment success and contribute to our understanding of infestation dynamics.

Prospective reports of head lice

The carers received a head lice information brochure and a white plastic lice comb ('PDC', KSL Consulting, Denmark) together with a questionnaire in September 2008, May 2009, November 2009 and June 2009. They were asked to register the months in which their child was found to be infested. We received reports for the following time periods: Period 1 (October–December 2008), Period 2 (January–June 2009), Period 3 (July–November 2009) and Period 4 (December 2009–May 2010). The questionnaires also included information of costs and actions taken against head lice, but this is dealt elsewhere (6). Note that the time periods diverge slightly between the two studies.

Individual and household characteristics

Individual hair characteristics were scored at the screening: thickness (fine, medium or thick), colour (black, brown, red or fair), type (straight, wavy or curly) and length (short: above the top of the ear, medium: from ear to shoulder or long: below the shoulder). The estimation of hair characteristics was synchronized among the observers at a test screening prior to this study. Data from national registers were provided by Statistics Norway based on the National Insurance number and provided the following information about each school child: gender, the identity of siblings living in the same household, number of carers, number of children <16 years in the household, country of origin defined as parents' birth place [grouped as Norwegian, Western (North America or Europe without Norway) and developing countries (Asia, Africa or South America)], mother's and father's working hours (short: <30 hours per week, long: >30 hours per week), mother's and father's highest education level (primary school, secondary school or higher education) and total household income [low: <500 000 Norwegian Krone (NOK) (1.0 NOK ≈ €0.125 at the time of the study), medium: 500 000–875 000 NOK or high: >875 000 NOK]. The variable Siblings with lice (with/without) represented siblings taking part in our investigation, and they therefore had a known infestation status.

Statistical analyses

To investigate the importance of different variables as head lice risk factors, data from the previous history (retrospective approach), screening (point prevalence) and Period 3 in the prospective report were used. The rationale for only using one prospective period in the analyses and not combining all four was that a different subset of students participated in the different periods. Period 3 was chosen over Period 1 and 2 based on the lower dependency on the screening

and reported history data (separated by 1 year), and over Period 4 based on the higher participation rate. First, children with and without head lice (dependent variable) in the three selected datasets were tested against all household and individual variables in univariate logistic regression. Thereafter, all individual and household variables significant at $P < 0.15$ in the univariate analysis were entered into a multivariate mixed model with class and school affiliation as random effect variables (class nested in school). The high P -value ($P < 0.15$) was used to ensure that no important variables were excluded from the final models. Several predictor variables were correlated (online Supplementary 1). Due to the low number of children with lice in the screening (low statistical power), only the most significant of the correlated variables in the univariate analysis was entered into the full model. Father's education level was removed from the full model of reported history due to collinearity with fathers working hours. The significance of the random variables was calculated by comparing the model with and without the random variable by a likelihood ratio test.

To estimate turnover in head lice infestations, we used data from all four prospective periods, screening and previous history and compared these by univariate logistic models. We estimated length of individual head lice infestations by combining Period 1 and 2 (collected by the same questionnaire) in the prospective reports allowing for one 9-month period of monitoring in addition to a 5- and 6-month period (Periods 3 and 4, respectively).

The data were analysed in the statistical software STATA v.10. For the multilevel analyses, the program, generalized linear latent and mixed models (gllamm), within STATA was used. The adaptive quadrature option was used, and the model was binomial with a logit link function. No missing values were accepted in the analyses.

Results

Participation and overall prevalence

The head lice history was reported by 44.3% of the 5663 primary school children from the 12 schools that were invited to participate, whereas 63.5% volunteered to be screened for head lice (Table 1). During the succeeding periods of prospective report, participation dropped to approximately one-third, with the lowest response during Period 4. A total of 608 children participated during the whole study. Participation varied strongly between schools, but the highest

and lowest participation was found at the same schools throughout the study.

Only 1.7% (62) of the children were infested with head lice at the screening (Table 1). During each 3–6-month period in the prospective report, an average of 3.2–6.0% of the children experienced head lice. Prior to the screening, 41.1% of the children had experienced head lice at least once (reported history). This experience with pediculosis increased from the age of 6 (first grade) to the age of 10 (fifth grade) where it levelled off (percentage having been infested sorted by increasing age: 21, 31, 43, 46, 55, 55 and 45). The prevalence at schools did not depend on participation in either dataset (linear regression, $P > 0.15$).

Main determinants of head lice prevalence

Having a sibling with lice was the overall most important factor for getting head lice at all three time periods investigated (Tables 2–4), increasing the chances [odds ratio (OR)] by 7, 36 and 26 times in the reported history, screening and prospective report, respectively. Four hair characteristics significantly influenced the chances of head lice infestation, but only hair length, with increased chances in medium long and long hair relative to short, was significant in more than one dataset ($P = 0.058$ in prospective report). Hair length correlated with sex; short hair was found almost exclusively on boys (0.2% girls), long hair almost exclusively on girls (99.7% girls), whereas medium hair was a mix of both sexes (49.8% girls). No household characteristics were strictly significant in any dataset. Children with a foreign background was strongly over-represented among those with an unsuccessful treatment when we rechecked 1 month after screening [univariate analysis, most significant variable among tested households characteristics; $P < 0.001$, Norwegian background: OR = 1, Western background: OR = 24.17 [confidence interval (CI): 2.40–245.90], background from developing country: OR = 17.85 (CI: 2.02–157.80)].

The random variables showed a greater variance between classes than between schools in all three analyses (Tables 2–4). Class were significant in two models, but school was only significant in one. This indicates a larger importance of class than school affiliation for the risk of getting head lice.

Infestation dynamics

Head lice prevalence varied between schools in all periods (Table 1), but no school remained high throughout all data collections (online

Table 1. Participation and overall prevalence of head lice in five data collections of primary school children in Oslo, Norway

% participation				% prevalence		
Data collected	Total (N)	School, minimum–maximum	Grade per school, minimum–maximum ^a	Total (N)	School, minimum–maximum (N)	Class, minimum–maximum (N) ^b
Reported history	44.3 (5663)	18.4–62.0	0.0–83.0	41.4 (2510)	29.5–57.8 (12)	0.0–100.0 (230)
Screening	63.5 (5663)	30.5–83.4	4.0–95.2	1.7 (3596)	0.0–3.4 (12)	0.0–16.7 (241)
Prospective report						
Period 1 ^{c,d}	35.7 (5246)	17.3–49.6	0.0–83.5	3.2 (1875)	0.0–7.6 (11)	0.0–100.0 (213)
Period 2 ^{c,d}	35.7 (5246)	17.3–49.6	0.0–83.5	3.4 (1875)	0.0–4.7 (11)	0.0–50.0 (213)
Period 3 ^e (fall)	35.5 (4930)	15.7–49.2	7.8–64.1	5.8 (1750)	0.7–10.3 (12)	0.0–44.4 (197)
Period 4 ^e (spring)	28.2 (4930)	10.8–47.9	5.3–68.4	6.0 (1392)	0.7–16.9 (12)	0.0–100.0 (195)

^aThe total number of children was only available to us per grade (age).

^bThe large values in prospective reports are outliers due to only infested children reporting from one class.

^cOne school chose not to participate.

^dPeriods 1 and 2 were collected in one questionnaire at the end of Period 2 and therefore had the same participants.

^eSeventh grade (age 12) children (733 persons) had left school.

Table 2. Multivariate, mixed-effect logistic regression of reported head lice history (lice/no lice) in primary school children at 12 schools in Oslo, Norway

Variable	P-value	Category	Prevalence (n)	OR (95% CI)
Siblings with lice	<0.001	No	34.7% (2075)	1
		Yes	76.4% (398)	7.18 (5.41–9.52)
Sex	0.902	Female	45.4% (1284)	1
		Male	37.1% (1189)	0.98 (0.68–1.40)
Grade (age)	<0.001	Continuous		1.26 (1.18–1.35)
Hair thickness	<0.001	Fine	32.4% (744)	1
		Medium	42.5% (1127)	1.67 (1.32–2.11)
		Thick	50.5% (602)	2.18 (1.64–2.91)
Hair colour	0.570	Light	42.2% (1476)	1
		Red	47.1% (51)	1.17 (0.61–2.26)
		Brown	45.2% (557)	1.08 (0.85–1.38)
		Black	32.1% (389)	0.79 (0.48–1.32)
Hair type	0.018	Straight	40.2% (1861)	1
		Wavy	49.2% (439)	1.35 (1.06–1.74)
		Curly	34.7% (173)	0.79 (0.53–1.18)
Hair length	<0.001	Short	23.7% (1163)	1
		Medium	86.4% (339)	1.91 (1.41–2.60)
		Long	46.9% (971)	1.61 (1.05–2.47)
Family background	0.385	Norwegian	43.4% (1688)	1
		Western	42.9% (345)	0.91 (0.69–1.21)
		Developing	32.7% (440)	0.73 (0.45–1.16)
Working hours of mother	0.063	Short	43.4% (839)	1
		Long	40.4% (1634)	0.82 (0.67–1.01)
Working hours of father	0.209	Short	36.5% (457)	1
		Long	42.5% (2016)	1.18 (0.91–1.52)
Education of mother	0.914	Primary	32.6% (386)	1
		Secondary	39.2% (618)	1.05 (0.75–1.46)
		Higher	44.7% (1469)	1.07 (0.78–1.48)

Class and school affiliation were used as random variable with class nested in school. Total number of children was 2473 from 229 classes. ORs are in relation to the first category of each variable. All variables added were significant at $P < 0.15$ in univariate analysis.

Random effect variance (CI): class = 0.31 (0.14–0.48); $P < 0.001$, school = 0.12 (–0.01 to 0.25), $P < 0.001$.

Table 3. Multivariate, mixed-effect logistic regression of head lice (lice/no lice) in primary school children at 12 schools in Oslo, Norway, at date of screening

Variable	P-value	Category	Prevalence (n)	OR (95% CI)
Siblings with lice	<0.001	No	1.4% (3522)	1
		Yes	37.0% (27)	35.95 (13.90–93.01)
Hair thickness	0.418	Fine	1.1% (990)	1
		Medium	1.4% (1639)	1.04 (0.48–2.24)
		Thick	2.7% (920)	1.72 (0.77–3.87)
Hair colour	0.088	Light	0.9% (1962)	1
		Red	1.3% (77)	1.50 (0.19–11.63)
		Brown	2.1% (816)	2.14 (1.07–4.31)
		Black	3.3% (694)	2.39 (1.09–5.23)

Class and school affiliation were used as random variable with class nested in school. Total number of children was 3549 from 241 classes. ORs are in relation to the first category of each variable. Only variables significant at $P < 0.15$ in univariate analysis are included. Of those correlated (hair colour, family background, cares education and working hours: online [Supplementary 1 and 2](#)), only the strongest response (hair colour) is included in the model.

Random effect variance (CI): class = 0.24 (–0.42 to 0.90), $P = 0.436$; school = 0.08 (–0.28 to 0.44), $P = 0.602$.

[Supplementary 3](#)). Having experienced head lice, the chances of still being infested decreased with time since last infestation ([Table 5](#), highest ORs along the diagonal for all estimates). Having been infested in the screening increased the chances by almost 14 times in the following 3 months (Period 1). Comparing the successive 3–6-month periods in the prospective reports, having head lice in one period increased the chances (OR) by 7.6, 2.7 [non-significant (ns)] and 10.0 times in the next, which represented an average OR of 6.5. Comparing the chances for getting lice having experienced it once in

the past (reported history), there was a 3.7 times higher chance of head lice at screening, but no (OR = 1.0) or a slightly higher chance (OR < 2.5) when compared with later estimates in the prospective report. Thus, although previous experience could have increased the odds for of future infestations, this effect diminished over time. Comparing none-successive prospective reports show the same pattern with an OR of 1.1 (ns), 2.0 (ns) and 2.4 for repeated infestations.

The duration of an individual infestation were collected from 317 infestations reported within three (Periods 1 and 2 combined)

Table 4. Multivariate, mixed-effect logistic regression of reported head lice (lice/no lice) in a prospective 5-month period (Period 3) in primary school children at 12 schools in Oslo, Norway

Variable	P-value	Category	Prevalence (n)	OR (95% CI)
Siblings with lice	<0.001	No	5.1% (1695)	1
		Yes	55.2% (29)	25.64 (10.30–63.81)
Sex	>0.999	Female	6.7% (875)	1
		Male	5.1% (849)	0.98 (0.46–2.11)
Hair type	0.237	Straight	5.7% (1304)	1
		Wavy	8.0% (299)	1.47 (0.86–2.51)
		Curly	3.3% (121)	0.66 (0.22–1.93)
Hair length	0.058	Short	4.9% (839)	1
		Medium	8.4% (239)	2.23 (1.10–4.49)
		Long	6.3% (646)	1.61 (0.62–4.17)
Income	0.242	Low	6.2% (469)	1
		Medium	6.9% (759)	1.14 (0.68–1.93)
		High	4.2% (496)	0.71 (0.38–1.34)

Class affiliation was used as random variable. Total number of children was 1724 split into 197 classes. ORs are in relation to the first category of each variable. All variables added were significant at $P < 0.15$ in univariate analysis.

Random effect variance (CI): class = 0.88 (0.11–1.66), $P < 0.001$; school = 0.08 (–0.21 to 0.38), $P = 0.506$.

Table 5. Univariate logistic models showing the chances of getting head lice (OR, CI) in a given period if head lice were experienced in another

Response variable	Explanatory variable				
	Reported history	Screening	Period 1 ^a	Period 2 ^a	Period 3
Screening	3.7 (2.0–7.0) ^{***} (2509)	–	–	–	–
Period 1 ^a	1.9 (1.1–3.3) [*] (1471)	13.8 (5.8–32.8) ^{***} (1874)	–	–	–
Period 2 ^a	2.5 (1.4–4.5) ^{***} (1471)	9.1 (3.6–23.5) ^{***} (1874)	7.6 (3.7–15.5) ^{***} (1875)	–	–
Period 3	1.6 (1.0–2.5) [*] (1343)	2.1 (0.6–7.3) (1750)	1.1 (0.2–4.5) (1144)	2.7 (0.9–7.9) (1144)	–
Period 4	1.0 (0.6–1.7) (1090)	4.5 (1.8–11.4) ^{**} (1392)	2.0 (0.6–6.7) (926)	2.4 (1.1–5.4) [*] (926)	10.0 (4.9–20.1) ^{***} (1038)

Period 4 and reported history represent the most distant measures in time. N for each analysis is given in parenthesis below the statistics. ORs in bold indicate significant^b (<0.05) interactions.

^aData from Period 1 was collected simultaneously.

^bP-values: *0.01–0.05, **0.01–0.001, *** <0.001 .

prospective data collections. Most infestations were reported from one month only (82.4%), while 14.9% were reported in two consecutive months and 2.7% in three consecutive months or more. As many as 10.2% of the children who experienced head lice reported discontinuous infestations within the three 5–9-month periods of data collection. Searching for children with very long infestations by combining all data across collection periods, the most frequent/longest any child was infested was 8 out of 16 reported months (Period 3 not reported), and this child also had a sibling that was infested for 6 months. All other children reported head lice for 4 months or less throughout these collections. The duration of head lice attacks was also indicated by the rechecking of infested children after screening. Of the initial 62 children with head lice, 22.6% (14) were still infested after 1 month.

Conclusions

Statement of principal findings

In this school-based study of head lice among children aged 6–12 years, siblings with lice was the most important predictor of

head lice. Having short hair halved the chances of infestation. Class affiliation was more important than school affiliation for the chances of getting lice. Having head lice in one school term increased the odds of an infestation in the next, but no persistently high- or low-prevalence schools were identified. Hardly any long-time infested children were discovered and 97.3% of reported infestations lasted shorter than 3 months. However, 22.6% of infested children still had lice 1 month after screening when rechecked.

Main determinants of head lice

Transmission of head lice was expected to be highest between household members and among children with close contact such as classmates, and our results fit well with this prediction; the chances of getting head lice was very high if a sibling had lice in all data collections, and class affiliations appeared more important than school in all datasets. The larger importance of class versus school was also found by Willems *et al.* (10) in Belgium, and Speare and Buettner (12,18) in Australia further pointed at classes as the major arena of transmission. These social arenas are likely to be essential for the dynamics of head lice infestations in a local community; a child

gets infested by a classmate and brings head lice into the household, where the lice spread to other family members. An infested sibling thereafter brings the lice to a new school class infesting new children and households. The importance of community transmission has been nicely identified in poor areas in Brazil; initially lice free children still got infested although their family members were treated with ivermectin and therefore remained free of head lice (19). Also, the increasing prevalence with higher population densities in Norwegian cities indicates the importance of community transmission (3). Clearly, future studies of head lice should ensure to include the social context of infested individuals.

The importance of hair length has been reported earlier (6,10) and can be linked to head-to-head contact needed for inter-head dispersal (8) and the overall increased risk for longer hair to touch other persons' hair. The fact that girls have more head lice than boys (4) may also relate to hair length, but differences in social contact pattern may represent another explanation. In studies combining sex, hair length and clustering of children into classes, hair length proved more important than sex in one study (10) whereas less important in another (13). Our data indicate that medium long hair (from ear to shoulder) increase the chances of head lice more than do long hair. This indicates that hair length is indeed more important than sex as no boys have long hair whereas medium hair is found equally in both sexes. Long hair is also often braided or tied in a ponytail decreasing the risk of hair-to-hair contact relative to slightly shorter hair. Risk of hair-to-hair contact may also explain the effect of hair thickness in the reported history; the thicker the hair, the higher the risk of contact.

Infestation dynamics

The low point prevalence in the present study corresponds to the 1.6% self-reported prevalence among primary school children in different parts of Norway (3) and is among the lowest in Europe (1). Even so, about half of the children will have experienced head lice before the age of 12. This clearly underlines the dynamic nature of the head lice infestations in Norway.

We expected that if insufficiently treated or untreated infestations are common, these are likely to represent a core of infested children that should be detectable at several points in time. Our results contradicted this expectation: we found no consistently high-prevalence schools, only one long-term infested household and almost no children with head lice in more than two consecutive months. The two latter results correspond well with the eagerness to act upon infestations found in our earlier questionnaires (5,6). Thus, the short duration of detected infestations combined with the intermittent infestations experienced by 10% of infested children point towards unnoticed transmission between social contacts as a primary driver of head lice infestations at outbreak. However, rechecking of infested children after screening indicate that some households do indeed struggle with treatment. Thus, we cannot rule out that some long-time infested children may increase head lice prevalence locally.

Limitations of study

The response rate was 60% or less, and we do not know whether the participating children were representable for the total population at schools. However, we did show that the prevalence in our study did not correlate with overall participation as was the case in Counahan *et al.* (13), and this at least indicates some independency with the results and participation. Also, we based our interpretation on the

results from several datasets, which increases the robustness of our conclusions. Screening assured that all children were checked by the same persons, reducing the probability of any systematic inspection errors and gave the highest number of participants. However, screening also depends on the carers' consent, which enabled worried parents to screen and treat their children before the school was visited. The reported history data depend on awareness of head lice in the past as well as ability to read and complete the questionnaires. The prospective report primarily depended on Norwegian literacy. Although the ability to read and fill in Norwegian questionnaires might have affected the outcome of the reported data compared to screening, the proportion of participating households with a foreign background and mothers with only primary school was at least similar in the screening and self-reported data collections [proportion of foreign households: 0.36 (screening), 0.32 (reported history) and 0.33 (prospective report); proportion of mothers with only primary school: 0.19 (screening), 0.15 (reported history) and 0.14 (prospective report)]. Ideally, an investigation of head lice dynamics should be based on multiple screenings as this probably includes the best subset of children. However, this is extremely labour intensive in low-prevalence areas and therefore unlikely to be realized in a setting like ours.

Implications for clinicians and policymakers

The present study showed the importance of households and school classes for head lice transmission, and these arenas should be the prioritized units for health care providers in Norway and most likely in other comparable developed countries. General guidance should be promoted in all households and schools, with some modifications as described by Rukke *et al.* (6), as no groups stood out as particularly troubled with head lice.

Our results showed that head lice infestations are very dynamic and that prolonged infestations in particular groupings of children are unlikely to be the major driver of head lice infestations in Norway. This supports our earlier study suggesting that frequent and thorough checking routines in all groupings are the most important preventive action against head lice in Norway, as it will decrease the infectious period of each child (5). Biannual nationwide campaigns supported by schools are important in this aspect as they improve checking frequency (5,6). However, we should be aware that households with extra need for support may also exist. In particular, information about preferred treatment methods should be distributed in the mother tongue of the carers. Direct help to these families from health care personnel may also be considered, treating the children and other household members if needed. This is in line with earlier recommendations suggested by Mumcuoglu *et al.* (20).

Since there is a very high risk of transmission within households, all school classes with children from the same household should be alerted when an infestation is detected. This should be possible in Norway as communication around infestations is generally good (5,6). Also, since infestation remains locally from one school term to the next, monthly remainders of checking should be considered for the first 6 months after a discovered outbreak, independent of new infestations being reported. Synchronized inspection and subsequent treatment remain the best strategy to remove a collective infestation within a short time (21).

The generality of our recommendations is difficult to predict, but they are likely to apply in comparable, developed countries with low prevalence of head lice such as the Nordic countries.

Supplementary material

Supplementary material is available at *Family Practice* online.

Acknowledgements

The participating households, staff of the schools and Nina Huynh are thanked for their efforts with data collection. Nina Huynh also provided valuable help with the questionnaires. The study was supported by the Norwegian Institute of Public Health to improve public health guidelines and head lice control in Norway.

Contributors

TB, BAR, HHL, AS and PO planned and designed the study. BAR, HHL, AS and PO supervised and carried out the screening. TB, PO, HHL, AS and BAR organized and managed the questionnaires. TB, BAR and ØN analysed the data. TB and BAR wrote the manuscript, which was critically reviewed and revised by the other co-authors. BAR and TB are project guarantors.

Declaration

Funding: Norwegian Institute of Public Health.

Ethical approval: the study was approved by the Data Protection Agency of Norway and Regional Committees for Medical and Health Research Ethics in Norway. All carers actively granted participation of their children in the study. The data provided by Statistics Norway were owned by the Norwegian Labor and Welfare Administration (NAV), Norwegian Tax Administration (Skattedirektoratet) and Ministry of Education and Research (Kunnskapsdepartementet), and the use of these data was also approved by each of these institutions.

Conflict of interest: all authors completed the ICMJE uniform disclosure form at http://www.icmje.org/coi_disclosure.pdf and declare no support from any organization for the submitted work; no financial relationships with any organizations that might have had an interest in the submitted work in the previous 3 years and no other relationships or activities that could appear to have influenced the submitted work.

References

- Falagas ME, Matthaiou DK, Rafailidis PI, Panos G, Pappas G. Worldwide prevalence of head lice. *Emerg Infect Dis* 2008; 14: 1493–4.
- Burgess IF. Human lice and their management. In Baker JR, Muller R, Rollinson D (eds). *Advances in Parasitology*. San Diego, CA: Academic Press, 1995, pp. 271–341.
- Rukke BA, Birkemoe T, Soleng A, Lindstedt HH, Ottesen P. Head lice prevalence among households in Norway: importance of spatial variables and individual and household characteristics. *Parasitology* 2011; 138: 1296–304.
- Heukelbach J (ed). *Management and Control of Head Lice Infestations*. Bremen, Germany: UNI-MED Verlag AG, 2010.
- Rukke BA, Birkemoe T, Soleng A, Lindstedt HH, Ottesen P. Head lice in Norwegian households: actions taken, costs and knowledge. *PLoS One* 2012; 7: e32686.
- Rukke BA, Soleng A, Lindstedt HH, Ottesen P, Birkemoe T. Socioeconomic status, family background and other key factors influence the management of head lice in Norway. *Parasitol Res* 2014; 113: 1847–61.
- Jahnke C, Bauer E, Feldmeier H. Pediculosis capita in childhood: epidemiological and socio-medical results from screening of school beginners [German]. *Gesundheitswesen* 2008; 70: 667–3.
- Canyon DV, Speare R, Muller R. Spatial and kinetic factors for the transfer of head lice (*Pediculus capitis*) between hairs. *J Invest Dermatol* 2002; 119: 629–31.
- Takano-Lee M, Edman JD, Mullens BA, Clark JM. Transmission potential of the human head louse, *Pediculus capitis* (Anoplura: Pediculidae). *Int J Dermatol* 2005; 44: 811–6.
- Willems S, Lapeere H, Haedens N *et al*. The importance of socio-economic status and individual characteristics on the prevalence of head lice in schoolchildren. *Eur J Dermatol* 2005; 15: 387–92.
- Mossong J, Hens N, Jit M *et al*. Social contacts and mixing patterns relevant to the spread of infectious diseases. *PLoS Med* 2008; 5: e74.
- Speare R, Buettner PG. Head lice in pupils of a primary school in Australia and implications for control. *Int J Dermatol* 1999; 38: 285–90.
- Counahan M, Andrews R, Büttner P, Byrnes G, Speare R. Head lice prevalence in primary schools in Victoria, Australia. *J Paediatr Child Health* 2004; 40: 616–9.
- Burgess IF. *Pediculus humanus capitis* in schoolchildren. *Lancet* 1995; 345: 730–2.
- Stone P, Wilkinson-Herbots H, Isham V. A stochastic model for head lice infections. *J Math Biol* 2008; 56: 743–63.
- Ibarra J, Fry F, Clarice W *et al*. Overcoming health inequalities by using the Bug Busting ‘whole-school approach’ to eradicate head lice. *J Clin Nurs* 2007; 16: 1955–65.
- Norwegian Pharmacy Organization. *Økning i salg av lusemidler*. <http://www.apotek.no/Default.aspx?ID=6918&PID=24093&NewsID=532> (accessed on 10 August 2015).
- Speare R, Buettner PG. Hard data needed on head lice transmission. *Int J Dermatol* 2000; 39: 877–8.
- Pilger D, Heukelbach J, Khakban A *et al*. Household-wide ivermectin treatment for head lice in an impoverished community: randomized observer-blinded controlled trial. *Bull World Health Organ* 2010; 88: 90–6.
- Mumcuoglu KY, Barker SC, Burgess IE *et al*. International guidelines for effective control of head louse infestations. *J Drugs Dermatol* 2007; 6: 409–14.
- Ibarra J, Fry F, Wickenden C, Jenner M, Franks A. The impact of well-developed preventative strategies on the eradication of head lice. *Perspect Public Health* 2009; 129: 165–73.