Vaccine coverage for kindergarteners: Factors associated with school and area variation in Vancouver, British Columbia

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**Introduction:** We investigated the extent to which school-specific kindergarten vaccination up-to-date status prevalence differs by public and private school types, student demographic composition, and geographic location across schools in Vancouver, and four adjacent British Columbia communities, during 2013–14.

**Methods:** School-specific kindergarten coverage for seven vaccinations plus up-to-date status were merged with data on school type and student sociodemographic composition for 219 schools within 9 Local Health Areas (LHAs).

**Results:** In adjusted Tobit regression models, private non-religious (versus public) schools were associated with lower up-to-date status ($b = -9.51$ percentage points). Student enrollment was positively associated with higher coverage, while greater number of English Language Learners (ELL), students speaking English at home, and Aboriginal students were each negatively associated with up-to-date coverage. The most socioeconomically disadvantaged and advantaged LHAs had the lowest coverage.

**Conclusion:** Our findings identify lower coverage among some types of private schools and in affluent and disadvantaged communities—and corroborate documented US coverage patterns. Future studies need to investigate school and community factors that may contribute to such patterns, in order to identify potential mechanisms and design appropriate interventions to increase vaccine coverage.

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for school entry, so PBEs and school vaccination coverage rates have not been closely examined and existing studies identifying school- and student sociodemographic composition-specific characteristics of school vaccination coverage outside of the US are limited.

The present analysis contributes international evidence to this emerging literature by investigating the extent to which school-specific kindergarten vaccination up-to-date status prevalence differs by school type (i.e. public and private schools), demographic composition, and geographic location across elementary schools in Vancouver and four adjacent communities in the lower mainland of British Columbia (BC), Canada during 2013–14. This west coast, Canadian metropolitan area of approximately 993,000 people across the five jurisdictions is not only important to examine in its own right, but provides a useful international comparison for several reasons: it contains a variety of public and independent (private) school types, a substantial degree of ethnocultural diversity and immigrant concentration; a mix of highly affluent and highly disadvantaged neighborhoods; a single-payer health care system, which covers all child vaccination costs; and is serviced by one public health authority (Vancouver Coastal Health Authority [VCH]). Though BC, like many Canadian provinces, does not mandate that children need to be vaccinated to attend school [9], children receive their school-entry vaccinations either from their family physician or public health nurses at their local health unit, or at school [10]. Each fall, all kindergarten children’s vaccination status is checked by public health nurses upon school entry and vaccination clinics are held in the community and at most schools to ensure children are up-to-date. Despite these measures, up-to-date rates for nearly all routine vaccines from 2011 to 12 were under 90% [10].

2. Method

Our analyses focus on public and private schools with kindergarten classes located within Vancouver and four adjacent cities in VCH’s jurisdiction: Richmond (bordering to the south), and the City and District of North Vancouver and West Vancouver (adjacent to each other and bordering Vancouver to the north). While VCH also serves several smaller rural and exurban areas further north, we focused on these four cities because they constitute the major urban areas of VCH’s jurisdiction and the majority of its service population. Also, their proximity enables residents in each locality to commute to work in any of the other cities and families to enroll children in schools located outside of their own city.

2.1. Sample

We linked VCH-compiled school vaccination coverage percent-ages with school characteristics and student composition demographics obtained from the British Columbia Ministry of Education’s 2013–14 annual school reports. Of the 226 public and independent schools in the four-city geographic area for which kindergarten coverage rates were available, five schools had masked vaccination data because of small class sizes (<5 children) and two other schools had no Ministry of Education school code to enable linkage to school demographic data. Hence, our analytic sample consists of 219 of 226 total schools.

2.2. School-specific vaccination coverage

School-specific kindergarten up-to-date coverage was defined as the percentage of kindergarteners (enrolled as of June 30, 2014) who were up-to-date on ten vaccine antigens: tetanus, diphtheria, pertussis, and polio (TDaP-P); measles; mumps; rubella; varicella; meningococcal C conjugate (hereafter, MenC); and hepatitis B all publicly reported by VCH [11]. Table 1 details VCH’s definitions used to determine up-to-date coverage for each antigen. Individual vaccine antigens were used (rather than specific vaccines) to allow for differences in the types of vaccines an individual may have received.

2.3. School type

We coded each school as: public (Anglophone and Francophone), French Immersion public, religious private, non-religious private, or Montessori/Reggio/Waldorf. The four Francophone public schools in our sample offer instruction for students who speak French as their primary or only language. French immersion program schools offer instruction in all subjects in French as a way for English speaking students to learn a second—i.e. Canada’s other official—language. These French immersion program schools do not always offer such instruction at the kindergarten level and do offer a traditional English-only track as well, but have been noted for enrolling students who are more likely to be native-born, non-English Language Learners (ELLs)/speaking English at home, without any special needs, and have university-educated, higher income parents [12,13]. Hence, French Immersion program schools are a proxy for higher socioeconomic status (SES) and have even been viewed as private schools within the public school system [13]. We limited our French Immersion coding to public schools offering such programs for kindergarteners (versus two other schools that offered it exclusively to older grades). Two

<table>
<thead>
<tr>
<th>Table 1</th>
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</thead>
<tbody>
<tr>
<td>Definitions for up-to-date status on ten vaccine antigens, Vancouver Coastal Health Authority, British Columbia [11].</td>
</tr>
<tr>
<td><strong>Vaccination</strong></td>
</tr>
<tr>
<td>Measles</td>
</tr>
<tr>
<td>Mumps</td>
</tr>
<tr>
<td>Rubella</td>
</tr>
<tr>
<td>Td-P</td>
</tr>
<tr>
<td>Varicella</td>
</tr>
<tr>
<td>Meningococcal C</td>
</tr>
<tr>
<td>Hepatitis B</td>
</tr>
<tr>
<td>Up-to-Date for all 10 antigens</td>
</tr>
</tbody>
</table>
private schools (one private religious and the other private, non-religious) also offered French Immersion programs, which we coded instead as private schools.

Our sample included a small number of public and private Montessori/Reggio programs and one private Waldorf school (11 total; seven public and four private). Hence, we combined these schools into one category because they all had an alternative curriculum (compared to traditional public and private school curriculums).

2.4. School demographic composition

Our four school demographic composition variables include total number of students in each school (as total students may confound any estimates observed for school type, since public schools are often larger than private schools), and the number of students per school who:

1. were English Language Learners (ELL; i.e., were learning English as a second language, which is also a good proxy for first generation immigrant status);
2. only/most frequently spoke English at home (an indicator of native-born and combined first and second generation immigrant households). This variable was not substantially correlated with ELL (Pearson r = -0.25);  
3. self-identified as being of Aboriginal ancestral identity [14]. Aboriginal people have been historically marginalized and represent one of the most socioeconomically vulnerable populations in BC and Canada overall. According to 2011 estimates, Vancouver had the third largest Aboriginal population (52,375) of all Canadian cities [15].

We utilized total students in each school because, for some schools, data for total kindergarten students was masked due to small numbers, which would have required us to drop these schools from our analysis. However, for schools with information on total students and total kindergarten students, the Pearson r correlation was 0.845 (Spearman r = 0.847), indicating that the former is an acceptable proxy for the latter. All four variables were natural log transformed for inclusion in our models.

2.5. Local Health Area

We also coded each school according to the Local Health Area (LHA) in which it was located. The majority of public school kindergarteners attend schools in their catchment areas or at least within their school’s LHA. Likewise, the spatial distribution of private schools is such that the majority of their students reside within the same LHA as the school itself. More than just proxies for school catchment areas, LHAs are important to consider because they:

(a) are catchment areas serviced by the local health authority and (b) capture the distribution of different sociocultural and socioeconomic populations throughout Vancouver and the surrounding communities.

The four jurisdictions within our study are served by nine LHAs: six within Vancouver and one each for Richmond, the combined City and District of North Vancouver, and West Vancouver/Bowen Island. (Schools serviced by West Vancouver’s LHA also include those on Bowen Island, a small, off-shore community accessible by ferry, from which many residents commute to work in the metropolitan Vancouver area and is included in the catchment area for West Vancouver public secondary schools.) The latter three LHAs correspond with the school boards for each of these areas; Vancouver has its own school district.

The compositional profiles for several of these LHAs are particularly noteworthy for our analysis. Vancouver’s Downtown Eastside (DTES) LHA services some of the most marginalized populations within VCH’s jurisdiction and is recognized for the extent of its concentrated disadvantage and high child vulnerability rates [16].

By contrast, Vancouver Westside contains the University of British Columbia and its highly educated residential community of faculty, staff, and graduate student families; as well as neighborhoods that, like the West Vancouver/Bowen Island and North Vancouver LHAs, are noted for residents with professional occupations and some of the most expensive housing prices in the Vancouver area [16,17].

Lastly, Richmond is well-known for its substantial Chinese ethnic population with a high prevalence of immigrants (one of the highest in Canada) [18]. 2011 census figures indicate that over 23% of Richmond residents reported most often speaking Chinese or Cantonese languages at home, with approximately 50% of all residents reporting languages other than English or French [19].

2.6. Analyses

We performed our analyses using Stata 13.1 (StataCorp, 2013). For modeling school vaccination coverage variation (a percentage truncated to 100%), we used two limit Tobit regression to account for the functional form of the outcome [20]. We report unstandardized slope (b) coefficients and standard errors (se). All estimates with p < 0.05 are noted as statistically significant.

To facilitate interpretation of results for log transformed school composition variables, we converted their slope coefficients back to their original scale values using the following formula, which estimates the percentage point change in a coverage percentage variable that is associated with the difference between the 75th and 50th percentile (original scale) values for the independent variable of interest: b * [log(75th percentile value)-log(50th percentile value)] [21].

3. Results

Wide variation in antigen-specific coverage existed in our sample—from 15% (TDaP-P) to 100% (all recommended vaccinations)—the lowest 25th percentile of school coverage was 67% for up-to-date status. Fig. 1 presents these distributions.

Table 2 presents estimates for school up-to-date percentages: unadjusted and adjusted for all the other aforementioned school type, student composition, and LHA variables in the model (supplementary results for each antigen-specific outcome comprising up-to-date status are reported in Table S1). These models exclude the lone Waldorf school in our sample because it was an outlier that had the lowest coverage percentage and, when included in models, exerted significant influence on the model estimates (data not shown).

For school type, the unadjusted models show that private religious (versus public) schools had significantly higher coverage for up-to-date status [b = 7.50 percentage points (pp)]. In the adjusted model, this estimate is attenuated to non-significance, while private non-religious schools had significantly lower coverage [b = −9.51 pp].

All four school composition factors are significantly associated with up-to-date coverage. For student enrollment (b = 10.07 pp), a 36% increase in student enrollment (on its original scale, the percentage increase from the median to the 75th percentile value) is associated with 3.10 pp higher up-to-date status percentage. For ELL student enrollment (b = −2.26 pp), a 100% increase in ELL students is associated with a lower expected coverage of −1.57 pp. For number of students speaking English at home, the association is negative (b = −3.34): a 70% increase in the number of students...
speaking English translates into a 1.77 pp decrease in coverage. Likewise, higher Aboriginal student enrollment was negatively associated with up-to-date status (−2.49 pp), such that a 150% increase in Aboriginal student enrollment is associated with a 1.28 pp decrease in coverage.

For Local Health Area (LHA), significant differences exist for the most disadvantaged and most affluent LHAs, but the Richmond LHA has the highest coverage compared to all other LHAs. The most disadvantaged LHA, Vancouver's Downtown Eastside (DTES), had −12.18 pp lower coverage. Among the most affluent LHAs (Vancouver Westside, North Vancouver and West Vancouver/Bowen Island), the latter two had the largest relative differences to Richmond for up-to-date status: 19.55 pp lower for North Vancouver and 29.84 pp lower for West Vancouver/Bowen Island, with both having the lowest coverage overall among all LHAs.

4. Discussion

We evaluated the extent to which school-specific kindergarten up-to-date status coverage for ten antigens differed by school type (i.e. public and private schools), demographic composition, and geographic location across elementary schools in Vancouver and four adjacent British Columbia communities during 2013–14. Our analysis contributes several important pieces of Canadian evidence to the growing, yet predominantly US-based literature.

First, consistent with US studies that identified private (particularly Montessori and Waldorf) schools as having higher PBE and vaccination refusal rates than public schools [6,7], we observed similar findings for private non-religious schools and the one Waldorf school in our sample, which had the lowest coverage percentages. Given the high tuition costs at most Vancouver-area private schools, lower vaccination coverage may be linked to higher SES families, although we were not able to directly assess this from our data.

Our findings also suggest lower coverage extends to both ends of the socioeconomic spectrum—i.e. in the most affluent and most disadvantaged communities in our sample. This finding is consistent with prior individual- and ecologic-level studies and suggests that low vaccination uptake among kindergarteners may be influenced by multiple mechanisms, including (for lower SES parents) access issues and time constraints that prevent health care visits and even providing signed consent for school vaccinations [23–25] as well as (for higher SES—possibly, higher educated—parents) concerns about vaccine safety that may lead to parental hesitancy and refusal [26]. Thus, identifying school-specific
patterns within and across LHAs is an important step for designing and evaluating effective public health education campaigns and service provision. Importantly, the reasons for the lower coverage, whether access or safety concerns, need to be identified in these schools.

Second, while we did not have specific data on race/ethnicity (beyond Aboriginal status), our findings indicate that higher prevalences of students mostly/only speaking English at home (a proxy for native born children), ELL students (an indicator of immigrant students) and Aboriginal students were each independently associated with lower school coverage percentages. Collectively, these differences suggest the need for more culturally-specific intervention efforts to increase school coverage. Though coverage was highest among schools in the Richmond LHA, which has substantial Chinese-Canadian and Chinese immigrant subpopulations (findings that corroborate other Canadian studies [27]), such coverage levels may be due to the high extent of data sharing between physicians and public health in this LHA, enabling more extensive immunization histories for children there versus in the other LHAs [28].

Third and finally, many of the initial (unadjusted) differences in coverage observed across school types were confounded by student composition and geographic location. In particular, religious (versus public) schools were initially found to have the highest coverage percentages for most of our outcomes, but this difference was attenuated to non-significant differences once other factors were controlled. In supplemental analyses (not shown here), we did not identify any one specific factor that was driving this result. Nevertheless, our analyses suggest that studies which fail to include such information in their models may be mis-estimating school-specific differences in coverage rates.

Several limitations are important to note. First, due to data availability, we examined school-level vaccination coverage rather than child-level vaccination levels/records. While generalizing our results from school- to child-level coverage risks an ecological fallacy about potential associations reported in this study, a school- and area-level analysis is conceptually and practically meaningful in the case of vaccinations and the community level protection they are designed to provide. Hence, it is necessary and useful for public health surveillance and program planning to identify school and community factors that correlate with school coverage rates—especially given existing research (highlighted at the outset of this paper) documenting geographic clustering of PBEs and undervaccination [4] and the gaps in community level protection such clustering may cause.

Second, with respect to sociodemographic data, (1) the extent of publicly available, school-specific student composition data collected by the BC Ministry of Education is limited (and self-identification of Aboriginal status is likely under-reported) and (2) there is a lack of extensive recent, and acceptable quality local area-level census data on SES, race/ethnicity, immigrant status, homeownership, and other useful variables as a result of the federal government canceling the 2011 long-form census (the traditional source for such detailed information). Currently no reliable source for such information exists in Canada. Despite these constraints, the sociodemographic and LHA indicators that we utilized in our models (along with well-known local knowledge about various community residential features) enabled us to triangulate information and gain useful insights for guiding current understanding and future studies about the social patterning of kindergarten vaccination in this large urban area.

Table 2
Study sample descriptive statistics and unadjusted and adjusted unstandardized slope coefficients (standard errors) from Tobit models regressing school-level up-to-date vaccination coverage percentage for kindergarteners on school type, student composition, and Local Health Area, Vancouver, British Columbia and surrounding communities, 2013–14.

<table>
<thead>
<tr>
<th>School type, No. (%)</th>
<th>Descriptive Statistics</th>
<th>School Up-to-Date Coverage Percentage*</th>
<th>Unadjusted</th>
<th>Adjusted**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 219)</td>
<td>b se</td>
<td>b se</td>
<td>b se</td>
</tr>
<tr>
<td>Public, Anglo-/Francophone</td>
<td>137 (62.6)</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>Public, French Immersion</td>
<td>29 (13.2)</td>
<td>-0.30 (2.88)</td>
<td>-3.28 (2.35)</td>
<td></td>
</tr>
<tr>
<td>Private, Religious</td>
<td>30 (13.7)</td>
<td>7.50** (2.85)</td>
<td>-3.44 (3.62)</td>
<td></td>
</tr>
<tr>
<td>Private, Non-religious</td>
<td>12 (5.5)</td>
<td>-8.26 (4.24)</td>
<td>-9.51** (4.13)</td>
<td></td>
</tr>
<tr>
<td>Montessori/Reggio/Waldorf</td>
<td>11 (5.0)</td>
<td>1.74 (4.62)</td>
<td>-0.91 (1.51)</td>
<td></td>
</tr>
<tr>
<td>School composition, mean (sd)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student enrollment</td>
<td>297.3 (143.0)</td>
<td>3.18* (1.53)</td>
<td>10.07*** (2.17)</td>
<td></td>
</tr>
<tr>
<td>English Language Learners</td>
<td>70.9 (72.4)</td>
<td>0.42 (0.54)</td>
<td>-2.26** (0.87)</td>
<td></td>
</tr>
<tr>
<td>Students speaking English at home</td>
<td>193.3 (147.0)</td>
<td>-1.91 (1.15)</td>
<td>-3.34* (1.48)</td>
<td></td>
</tr>
<tr>
<td>Aboriginal students</td>
<td>9.1 (17.0)</td>
<td>-2.14* (0.84)</td>
<td>-2.49** (0.82)</td>
<td></td>
</tr>
<tr>
<td>Local Health Area, No. of schools (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vancouver City Centre</td>
<td>6 (2.7)</td>
<td>-4.66 (4.83)</td>
<td>-5.63 (4.57)</td>
<td></td>
</tr>
<tr>
<td>Vancouver Downtown Eastside</td>
<td>9 (4.1)</td>
<td>-20.72*** (4.05)</td>
<td>-12.18** (4.16)</td>
<td></td>
</tr>
<tr>
<td>Vancouver North East</td>
<td>30 (13.7)</td>
<td>-5.96* (2.60)</td>
<td>-4.15 (2.58)</td>
<td></td>
</tr>
<tr>
<td>Vancouver Westside</td>
<td>29 (13.2)</td>
<td>-10.20*** (2.63)</td>
<td>-10.10*** (2.68)</td>
<td></td>
</tr>
<tr>
<td>Vancouver Midtown</td>
<td>18 (8.2)</td>
<td>-11.78*** (3.09)</td>
<td>-11.09*** (2.93)</td>
<td></td>
</tr>
<tr>
<td>South Vancouver</td>
<td>29 (13.2)</td>
<td>0.39 (2.63)</td>
<td>-0.52 (2.49)</td>
<td></td>
</tr>
<tr>
<td>Richmond</td>
<td>47 (21.5)</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>North Vancouver</td>
<td>34 (15.5)</td>
<td>-19.62*** (2.53)</td>
<td>-19.55*** (2.71)</td>
<td></td>
</tr>
<tr>
<td>West Vancouver/Bowen Island</td>
<td>17 (7.8)</td>
<td>-28.81*** (3.15)</td>
<td>-29.84*** (3.10)</td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05; ** p < 0.01; *** p < 0.001; sd = standard deviation; b = slope coefficient; se = standard error.

a All regression models based on n = 218 with single Waldorf school removed from analysis.

b For each school composition variable, the descriptive values indicate the mean (sd) of the number of students per school; these variables were natural log transformed for regression models shown.

c Up-to-date coverage for each school is percentage of kindergartners enrolled as of June 30, 2014 who received all completed series of ten vaccine antigens: measles, mumps, and rubella; varicella, TDaP; meningococcal C; and hepatitis B.

d Model estimates adjusted for all other variables listed in this table.
5. Conclusion

Our study contributes to west coast, urban Canadian evidence to the predominantly US-based literature on area-level variation in vaccination coverage. Future studies need to explore, in greater depth, school and community factors that may be contributing to such patterns, in order to identify potential mechanisms for under-vaccination and design appropriate community interventions. Specifically, a multi-pronged approach that aims to (a) utilize multilevel data (on schools, communities, families, and children); (b) apply conceptual, measurement, and analytic insights gained from neighborhood/school and network health effects research and (c) identifies potential natural experiments (e.g., policy changes) that create variation in vaccination uptake, offers great potential for informing efforts to achieve targeted coverage goals and adequate community immunity within and across schools and communities.

Conflict of interest

None.

Acknowledgements

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.vaccine.2016.10.001.

References