Clinical Communications

Adjusting for nonresponse bias corrects overestimates of food allergy prevalence
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TO THE EDITOR:
Nationally estimates of food allergy prevalence are frequently based on telephone surveys, as this allows population-based sampling from geographically diverse regions. The most recent study based on telephone surveys, as this allows population-based sampling from geographically diverse regions. The most recent study.
Developing nonresponse bias estimates
Developing weighted estimates of prevalence
Point estimates and 95% credible intervals (CrIs) for the prevalence of food allergy and probable allergy were weighted to account for the oversampling of vulnerable populations (refer to Supplement E2 in this article’s Online Repository at www.jaci-inpractice.org). Credible intervals are the Bayesian analogue to standard confidence intervals.
Developing nonresponse bias estimates
To develop nonresponse bias-adjusted estimates of prevalence of food allergy to any food, 4 groups were identified:
(1) Full Participants: households who completed the FAPQ,
(2) Refusal Questionnaire Participants: households who completed the RQ only,
TABLE II. Nonadjusted and bias-adjusted prevalence estimates of perceived allergy to any food

<table>
<thead>
<tr>
<th>Estimate number</th>
<th>Full participants (FP), % (95% CrI) (n = 15,022)</th>
<th>Nonparticipants (NP), % (95% CrI) (n = 17,059*)</th>
<th>Never reached participants (NRP), % (95% CrI) (n = 8419*)</th>
<th>All participants, % (95% CrI) (n = 41,893)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nonadjusted</td>
<td>Bias-adjusted</td>
<td>Nonadjusted</td>
<td>Bias-adjusted</td>
</tr>
<tr>
<td>1</td>
<td>6.4 (6.0, 6.8)</td>
<td>2.1 (1.4, 2.9)</td>
<td>NP half RQP 1.0 (0.7, 1.4)</td>
<td>1.1 (0.7, 1.5)</td>
</tr>
<tr>
<td>2</td>
<td>6.4 (6.0, 6.8)</td>
<td>2.1 (1.4, 2.9)</td>
<td>NP same as RQP 2.1 (1.4, 2.8)</td>
<td>2.1 (1.5, 2.9)</td>
</tr>
<tr>
<td>3</td>
<td>6.4 (6.0, 6.8)</td>
<td>2.1 (1.4, 2.9)</td>
<td>NP twice RQP 4.2 (2.8, 5.7)</td>
<td>4.3 (2.9, 5.9)</td>
</tr>
<tr>
<td>4</td>
<td>6.4 (6.0, 6.8)</td>
<td>2.1 (1.4, 2.9)</td>
<td>NP half RQP 1.0 (0.7, 1.4)</td>
<td>3.5 (3.2, 3.8)</td>
</tr>
<tr>
<td>5</td>
<td>6.4 (6.0, 6.8)</td>
<td>2.1 (1.4, 2.9)</td>
<td>NP same as RQP 2.1 (1.4, 2.8)</td>
<td>4.0 (3.6, 4.5)</td>
</tr>
<tr>
<td>6</td>
<td>6.4 (6.0, 6.8)</td>
<td>2.1 (1.4, 2.9)</td>
<td>NP twice RQP 4.2 (2.9, 5.7)</td>
<td>5.1 (4.4, 6.0)</td>
</tr>
<tr>
<td>7</td>
<td>6.4 (6.0, 6.8)</td>
<td>2.1 (1.4, 2.9)</td>
<td>NP half RQP 1.0 (0.7, 1.4)</td>
<td>6.4 (6.0, 6.9)</td>
</tr>
<tr>
<td>8</td>
<td>6.4 (6.0, 6.8)</td>
<td>2.1 (1.4, 2.9)</td>
<td>NP same as RQP 2.1 (1.4, 2.8)</td>
<td>6.4 (6.0, 6.9)</td>
</tr>
<tr>
<td>9</td>
<td>6.4 (6.0, 6.8)</td>
<td>2.1 (1.4, 2.9)</td>
<td>NP twice RQP 4.2 (2.8, 5.7)</td>
<td>6.4 (6.0, 6.9)</td>
</tr>
</tbody>
</table>

*The number of people in all nonallergic households in the RQP group, and in all households in the NP and NRP groups, was imputed using the distribution of the number of people in each household in the FP group.

(3) Nonparticipants: households who were reached by telephone but refused to complete either questionnaire, and

(4) Never Reached Participants: households who could not be reached by telephone.

Food allergy data were available only from Full and RQ Participants. Multiple imputation (MI), the gold standard for adjusting for missing data, was used to adjust the estimates for nonresponse bias that resulted from missing food allergy data within the Nonparticipants and the Never Reached Participants by using a model that included observed data (census tract [CT] and province of residence) to predict the missing data on the probability of food allergy.

A range of assumptions regarding the prevalence of food allergy in the Nonparticipants and Never Reached Participants were investigated (refer to Supplement E3 in this article’s Online Repository at www.jaci-inpractice.org). Compared with the prevalence in the RQ Participants living in the same CT, the prevalence in the Nonparticipants was assumed to be: (1) half, (2) equal to, and (3) twice as large as the RQ Participants.

Compared with the prevalence of those in the same CT, the prevalence among the Never Reached Participants was assumed to be: (1) equal to the Nonparticipants; (2) a weighted average of the Full, RQ, and Nonparticipants; and (3) equal to the Full Participants.

MI was implemented via a hierarchical logistic regression model with 4 levels: individual, household, CT, and province of residence. Weighting to account for the overrepresentation of vulnerable populations could not be done in this analysis because demographic information was only available for Full Participants. The analyses were performed using WinBUGS (version 1.4.3, MRC Biostatistics Unit, Cambridge, United Kingdom) (refer to Supplement E3 in this article’s Online Repository at www.jaci-inpractice.org).

RESULTS

Participation rate

We telephoned 17,337 households, 14,113 of whom were actually reached. Of these 14,113 households, 1351 were ineligible due to a language barrier or unavailability of an adult. Of the 12,762 eligible households, 5734 households, representing 15,022 individuals, completed the FAPQ (45% response rate, or 5734 of 12,762) and were thus Full Participants, 524 households completed the RQ (an additional 4%, or 524 of 12,762) and were thus RQ Participants, and the remaining 6504 households answered the telephone but refused to provide any information (51%) and were thus Nonparticipants. An additional 3224 households were never reached, and were thus Never Reached Participants.

Prevalence estimates

Among Full Participants, the unweighted self-reported (perceived) prevalence of allergy to any food was 6.4% (6.0%, 6.8%). After weighting, this estimate increased to 7.5% (6.9%, 8.1%) (Table I).

Compared with the Full Participants, the unweighted perceived prevalence of allergy to any food was lower among the RQ Participants (6.4% [6.0%, 6.8%] vs 2.1% [1.4%, 2.9%]) (Table II). Applying the different assumptions regarding the prevalence of food allergy among the Nonparticipants and Never Reached Participants, 9 selection bias-adjusted estimates were obtained for the perceived prevalence of allergy to any food ranging from 3.0% (2.8%, 3.3%) to 5.4% (4.8%, 6.1%) (refer to Table II and Supplement E3 in this article’s Online Repository at www.jaci-inpractice.org).

DISCUSSION

Comparison with previous studies

The unweighted perceived prevalence of food allergy in this study (6.4% [6.0%, 6.8%]) was less than that in our general population study conducted 2 years earlier (8.1% [7.5%, 8.7%]), but these estimates are not directly comparable as our current study targeted vulnerable populations. The weighted perceived prevalence in the current study (7.5% [6.9%, 8.1%]) is also lower than that estimated in the NHANES study, a US population-based door-to-door survey conducted between 2007 and 2010 (9.0% [8.3%, 9.6%]). The NHANES survey is weighted for nonresponse in general, but this weighting may not be sufficient to account for all possible nonresponse bias. However, our weighted perceived prevalence in children (6.9% [5.5%, 8.2%]) is similar to that estimated by Gupta in a US population-based
internet survey conducted between 2009 and 2010 (8.0% [7.7%, 8.3%]).
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Limitations

Although our response rate was only 45% (49% including the RQ Participants), other recent studies on food allergy prevalence have reported similar response rates.1–3 In fact, research has shown that the majority of telephone surveys report response rates below 50%.4 In addition, the information letter sent to participants before our telephone survey indicated (as required by our ethics board) that those with food allergy might need to complete a slightly longer questionnaire. It is possible, therefore, that those who participated were more likely to be allergic than those who did not. We have considered this by creating various imputation models, which assume different biases between responders and nonresponders. Finally, we had to impute the number of individuals in nonallergic households who completed the RQ because this information was not requested as we wanted to optimize the response rate by asking only a single question.

Conclusions and future directions

We are the first to consider the effect of nonresponse bias in the estimation of food allergy prevalence and have clearly demonstrated that doing so is crucial in developing accurate estimates. Despite survey response rates dropping in recent years, surveys remain an important methodology for population-based research. With low response rates, representativeness of survey participants is an important issue that must be addressed. We explored a range of assumptions for the prevalence of food allergy among Nonparticipants and Never Reached Participants and prevalence estimates ranged from 3.0% (2.8%, 3.3%) to 5.4% (4.8%, 6.1%). Given that the prevalence (unweighted) among Full Participants was 6.4% (6.0%, 6.8%), it is evident that nonresponse bias can substantially influence prevalence, and ignoring bias could result in an overestimation. Our research highlights the importance of minimizing nonresponse bias in designing a study, while acknowledging that bias is likely present and should be considered when performing the analysis.

References


SUPPLEMENT E1: SELECTION OF STUDY POPULATION

Canadians from low-income households, new Canadians (ie, less than 10 years living in Canada), and individuals who identify as Aboriginal were specifically targeted. Canadians with low levels of education were not targeted because it was anticipated that there would be substantial overlap between low income and low education, and by targeting low-income areas, those with low education would also be included.1

Adults having completed less than a postsecondary degree, trade certificate, or diploma were defined as being of low education. This group was restricted to individuals who are 18 years or older. Individuals were considered to be low income if their household income was below the low-income cutoff (LICO). The LICO is defined as an income level at which families or unattached individuals spend at least 70% of before-tax income on food, shelter, and clothing, and is determined according to family size and geographic location.2 New Canadians were those who immigrated to Canada within 10 years of completion of the telephone survey. Individual are considered to be of Aboriginal identity if they report “Aboriginal” as their cultural background and identify with First Nations, Métis, or Inuit.

Using the 2006 Canadian census, the 100 census tracts (CTs) from within the census metropolitan areas (CMAs) that contained either the highest proportion of households living under the LICO or the highest proportion of new Canadians were selected.3 Individuals of Aboriginal identity were selected in the same way using a lower threshold of 15%, which resulted in a total of 66 CTs included.

These CTs were then converted to postal codes using the 2006 Statistics Canada postal code conversion file. Then, InfoDirect (“White Pages” in Canada) selected a random sample of household telephone numbers with accompanying mailing addresses from these postal codes.

Due to this targeting strategy, CTs from the province of New Brunswick were not proportionately represented (only 2 CTs were included in the initial selection), and those from Nova Scotia and Newfoundland and Labrador were excluded from the initial selection because they were not among the top 100 in terms of proportion of low-income households or new Canadians, nor in the top 66 in terms of proportion of individuals of Aboriginal identity. Further, Prince Edward Island (PEI) and the 3 Canadian territories (Northwest, Yukon, and Nunavut) were excluded because they do not contain any CMAs, and hence there are no CTs.

Although our primary objective was to ensure adequate representation of the vulnerable populations, we also wanted to provide prevalence estimates involving populations from all Canadian provinces and territories. Hence, for New Brunswick, Nova Scotia, and Newfoundland and Labrador, CTs with the highest proportion of households under the LICO (range: 25.8% to 38.9% from 8 CTs in St John, New Brunswick; range: 24.1% to 40.9% from 10 CTs in Halifax, Nova Scotia; range: 27.4% to 41.4% from 5 CTs in St John’s, Newfoundland) were selected from the main CMAs. These areas contained too few new Canadians or individuals of Aboriginal identity to be included in the sampling for these populations. In PEI, we targeted the largest Census Subdivision in the province, Charlottetown. According to the 2006 Census, 13.2% of households in Charlottetown were below the LICO and 1.4% were new Canadians. In the Northwest and Yukon Territories, a random sample of households was selected from all areas. In Nunavut, all available records were purchased because of the large number of those of Aboriginal identity residing in this territory.

SUPPLEMENT E2: CREATING WEIGHTED ESTIMATES TO ACCOUNT FOR OVERSAMPLING OF VULNERABLE POPULATIONS

To create the weighted estimates, nonoverlapping subgroups of interest, each characterized by education, income, Canadian-born, and Aboriginal status, were created for both the study population and the 2006 Canadian Census database. The weight for each vulnerable group of interest was calculated by dividing the proportion of individuals in the Census who fall into this subgroup by the proportion of individuals in the SPAACE who fall into this same subgroup.

SUPPLEMENT E3: CREATING THE STATISTICAL MODELS FOR THE ANALYSIS OF NONRESPONSE

To account for missing data in our study, we used multiple imputation for both ignorable and nonignorable missing data, as proposed by Knetic et al.4 We created posterior distributions for the prevalence of food allergy for Full Participants, Refusal Questionnaire Participants, Nonparticipants, and Never Reached Participants, and mixtures of these posterior densities formed our final prevalence estimates. The prevalence of food allergy for the Full and Refusal Questionnaire Participants was estimated using data from the telephone survey, but to estimate the prevalence in the Nonparticipants and Never Reached Participants, for whom data on food allergy were missing, we created estimates across a range of clinically and statistically plausible assumptions.

Multiple imputation was used to adjust the estimates for nonresponse bias from missing food allergy data within the Nonparticipants and the Never Reached Participants by using a model that included observed data (CT and province of residence) to predict the missing data on the probability of food allergy.5 Multiple imputation is the gold standard for adjusting for missing data.6 It involves filling in missing values for the presence or absence of food allergy with a “best guess” that is based on the assumptions of bias described above. Ten thousand versions of the complete dataset were formed and data analysis was carried out on each dataset. To derive final inferences from the data, an average of the results from each of the ten thousand datasets was used as a point estimate for prevalence, with overall variance equal to the sum of within and between imputation variances.7 Point estimates and 95% credible intervals (CrIs) were estimated. A 95% CrI implies that there is a 95% probability that the parameter of interest falls within the upper and lower limit of the interval, given the data and prior information used. If low information priors are used, the 95% CrIs essentially reflect the information in the data.

Before running the multiple imputation programs in WinBUGS, the following preliminary steps were completed:

1. In households who completed the Refusal Questionnaire and indicated that 1 or more members had a food allergy, the number of allergic individuals was imputed because it was unknown how many individuals had a food allergy. The
number of allergic individuals in each household was imputed based on the distribution of the number of allergic individuals from the Full Participants.

2. The total number of individuals in the household was imputed for the Nonparticipants, the Never Reached Participants, and the nonallergic Refusal Questionnaire Participants, based on the distribution of the total number of individuals from the Full Participants.

3. The prevalence of food allergy in the Full Participants was estimated by taking the observed number of allergic people divided by the observed total number of people in this group, assuming a binomial distribution.

4. The prevalence in the Refusal Questionnaire Participants was estimated by taking the imputed number of allergic people (described in step 1) divided by the observed total number of people in those households who reported allergy plus the imputed total number of people in households who did not report allergy (described in step 2).

As detailed in the article, 3 assumptions regarding the prevalence of food allergy in the Nonparticipants and 3 assumptions regarding the prevalence in the Never Reached Participants were investigated, which yielded 9 different models, as follows:

1. The prevalence in the Nonparticipants is half that in the Refusal Questionnaire Participants, and the prevalence in the Never Reached Participants is the same as in the Nonparticipants.

2. The prevalence in the Nonparticipants is the same as in the Refusal Questionnaire Participants, and the prevalence in the Never Reached Participants is the same as in the Nonparticipants.

3. The prevalence in the Nonparticipants is half that in the Never Reached Participants, and the prevalence in the Nonparticipants is twice that in the Nonparticipants.

4. The prevalence in the Nonparticipants is half that in the Refusal Questionnaire Participants, and the prevalence in the Never Reached Participants is a mixture of the prevalence in the Full Participants, Refusal Questionnaire Participants, and Nonparticipants.

5. The prevalence in the Nonparticipants is the same as in the Refusal Questionnaire Participants, and the prevalence in the Never Reached Participants is a mixture of the prevalence in the Full Participants, Refusal Questionnaire Participants, and Nonparticipants.

6. The prevalence in the Nonparticipants is twice that in the Refusal Questionnaire Participants, and the prevalence in the Never Reached Participants is a mixture of the prevalence in the Full Participants, Refusal Questionnaire Participants, and Nonparticipants.

7. The prevalence in the Nonparticipants is half that in the Refusal Questionnaire Participants, and the prevalence in the Never Reached Participants is the same as in the Full Participants.

8. The prevalence in the Nonparticipants is the same as in the Refusal Questionnaire Participants, and the prevalence in the Never Reached Participants is twice that in the Nonparticipants.

9. The prevalence in the Nonparticipants is twice that in the Refusal Questionnaire Participants, and the prevalence in the Never Reached Participants is the same as in the Full Participants.

Multiple imputation was implemented via a hierarchical logistic regression model, with 4 levels: individual, household, CT, and province of residence. Each model had the same basic structure, as follows:

\[
\text{logit}(\text{prevalence}) = \text{intercept}_i + \text{household effect}(\text{number of individuals in household}) + \text{assumption about prevalence}(1 - 4, \text{unique for each of the 4 groups of participants})
\]

where the intercept depended on the CT and province (represented by “i” in the above equation). There were 13 provinces and 265 CTs. Province of residence and CT information was available for all households, regardless of participation level, and so was included for all subjects in the model. The analyses were carried out using WinBUGS (version 1.4.3, MRC Biostatistics Unit, Cambridge, United Kingdom).

REFERENCES