Comparing Different Methods to Detect and Correct Nonresponse Bias in Postal Questionnaire Studies

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Abstract

Objectives: *This study compares methods for detecting and correcting the bias associated with nonresponse to postal questionnaires.* ***Methods:*** *Questionnaires were sent out in three sequential stages to parents of all 5-year-old children examined in a clinical survey. Each stage progressively targeted nonresponders. Data on dmft and area measures of socioeconomic status were available for all children. Estimates for whole population dmft were produced by different methodologies comparing the relationship between dmft and stage of response and three area measures of socioeconomic status.* ***Results:*** *A total of 1,776 children were examined and 1,437 questionnaires were obtained, a response rate of 80.9 percent. The mean dmft of the total population (1.49) was 17.3 percent more than responders (1.27). The dmft of the nonresponders was 2.41, 89.7 percent more than responders. There were significant linear trends in dmft and socioeconomic status across the mailing stages. The methodology using mailing stage regressed against dmft produced the most accurate adjusted dmft value (1.42). The methods using area measures of socioeconomic status produced nearly identical adjusted dmft values ranging from 1.31 to 1.32.* ***Conclusions:*** *Even with an "acceptable" response rate, nonresponse bias can still be present. Researchers should report the outcomes of analyses to detect nonresponse bias when publishing questionnaire studies. [J Public Health Dent 2003;63(2):112-18]*

Key Words: questionnaires, dental health surveys (epidemiology), data collection.

Postal questionnaires are frequently used in health services surveys and research, and are seen as a cost-effective means of collecting data. However, postal questionnaire studies are bedeviled by worries over biased results due to low levels of response. Nonresponders to postal questionnaire surveys have been shown to be different from responders in terms of health outcomes and health-related behaviors (1-5). The principal reason for this difference is that nonresponders are more likely to come from disadvantaged backgrounds than responders (5,6). Consequently, nonresponse bias can lead to underestimation of the prevalence of health outcome variables, and to overestimations of service utilization due to the close inverse relationship between socioeconomic status and health and the close positive connection with health service use. The association between nonresponse and socioeconomic status can also provide a distorted picture of the true magnitude of health inequalities.

Methods have been developed to detect and, if present, correct for nonresponse bias. One approach has been to calculate sex-specific rates for an outcome variable within the responding population and apply these rates to the sex distribution of the nonresponding population (7). A more sophisticated method is based on the length of time taken to receive a response to the questionnaire. Using this methodology, questionnaires are distributed in three or four stages, each successive stage targets any remaining nonresponders. Subjects who respond in the later stages have been found have more in common with nonresponders than early responders (7,8). Researchers can have strong suspicions of the presence of nonresponse bias if important variables show a linear trend across the mailing stages. An estimated value for nonresponders can be produced by regressing cumulative percent with the condition or disease under examination against the cumulative percent of questionnaires returned over each stage and extrapolating a regression line past the data point for the final mailing stage (9). The problem with this methodology is that most multiple mailing strategies use only three mailing stages. Thus the regression line used to produce estimated values for nonresponders is constructed from only three data points, which causes concerns about the accuracy of this methodology (6).

A more accurate means of detecting and correcting nonresponse bias could come from the relationship between the health variable of interest and a proxy measure of the socioeconomic status of the subjects. To distribute postal questionnaires, an address is needed for each subject. In the United Kingdom this means postcodes are available for the entire study population. The UK postcode is an alphanumeric code identifing the location of a subject's area of residence. By reference to the postcode, area measures of socioeconomic status based on UK Census data can be readily attached to the records of all subjects. This provides a means by which proxy measurements of the socioeconomic status of responders and nonresponders can be compared. As most health-related variables are strongly associated with socioeconomic status (10), this comparison may provide a more accurate means of detecting and correcting nonresponse bias than the previously described sex-specific rates or Hochstim's successive stages model (8).

The purpose of this study was to compare methods for detecting and

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correcting the bias associated with nonresponse to postal questionnaires. More specifically, the aim was to examine the use of socioeconomic status as a means of identifying and compensating for nonresponse bias and to compare this method with others that have been reported previously. A secondary aim was to establish whether nonresponse bias significantly affected the reported magnitude of difference in health-related variables in deprived and affluent groups.

Methods

This study used data collected in a project that compared findings from a clinical dental survey of children carried out in 1999–2000 with questionnaire responses concerning parental assessment of the dental anxiety of the same subjects. The study population included all children involved in a UK National Health Service epidemiologic survey of all 5-year-old children attending state schools in Chester, UK. Children were examined for the presence of tooth decay by three trained and calibrated examiners according to standardized national criteria. The number of decayed, missing, or filled teeth (dmft) were recorded for each child.

The parents of all of the children examined in the clinical survey were sent a postal questionnaire. The principles of Dillman's Total Design Method (11) for postal surveys were broadly followed; however, three rather than four mailing stages were used. All subjects were included in the first mailing stage. After one month, the second mailing was sent out to all nonresponders. A third and final mailing was sent to all residual nonresponders one month later. The questionnaires sent out at each mailing stage were coded to identify the stage to which each response was received. The home postcode of each subject was collected and this enabled the Jarman Underprivileged Area (12) and the Townsend Material Deprivation (13) scores for the electoral ward of residence of every child to be attached to each record. These two area measures of deprivation are very commonly used in the United Kingdom. They are constructed from variables collected in the UK Census, completion of which is mandatory. This ensured that coverage of the 1991 Census was 97.8 percent. Electoral wards are local government electoral and administrative areas. The geographical and population size of wards varies according to location; however, in the northwestern region of the United Kingdom the mean ward population size in mid-1994 was 6,995. The Super Profiles geodemographic classification (14) also was attached to the records. This is another area measure of socioeconomic status derived from a much broader range of Census variables and data from commercial sources. The Lifestyle Group tier of the classification was used, comprising 10 groups plus an additional category of unclassified areas. Super Profiles classifies enumeration districts (EDs) rather than electoral wards. EDs are the smallest unit of the UK Census, comprising about 120 households and 400 individuals.

The study design ensured that clinical data on an important health outcome variable (in this case dmft) was available for both responding and nonresponding populations. Comparison of the mean dmft, mean Jarman and Townsend scores and sex distribution of each response stage, and of nonresponders, was used to detect the presence of nonresponse bias. Bivariate regression models were fitted for dmft using Jarman and Townsend scores associated with each subject as independent variables, after omitting nonresponders from the analyses. Each bivariate relationship enabled adjusted values for the total population dmft to be calculated by reference to the mean Jarman and Townsend scores of the nonresponding population. Further adjusted values were calculated by reference to the dmft of responders at successive stages, first, by following Hochstim by regressing cumulative dmft against cumulative response rate. The value of the variable of interest, assuming 100 percent coverage, is calculated using the simple regression equation $x=by+constant$, where $y=100$. Then regressing mailing stage as the independent variable against stage-specific means as the dependent variable and calculating the estimate for dmft of the nonresponders by the regression equation where $y=4$ (nonresponders being a fourth point on a scale where the mailing stages are points 1, 2, and 3).

More adjusted values were derived from subject's Jarman and Townsend scores and Super Profile Lifestyle groups using a different methodology. The responding population was divided into deciles according to both their Jarman and Townsend scores, and into the Lifestyle groups. Mean dmft values were constructed for each Jarman and Townsend decile and Lifestyle group using data from the responding population alone. These values were then applied to the nonresponding population to produce dmft estimates. The corrected dmft values derived from each methodology were compared with the observed dmft produced from the whole population clinical survey. The successive stages approach also was used to provide estimates of the magnitude and direction of nonresponse bias in the reported anxiety data obtained from the questionnaire.

The effect of nonresponse bias on the measurement of health inequalities was determined by splitting the responding population and total population into socioeconomic quintiles according to each subject's Jarman score. The percentage difference in dmft and caries prevalence between the most affluent and deprived quintiles were measured and compared. The location of the area of residence in responding, nonresponding, and total populations was also compared. The location used in this instance was the Primary Care Groups (PCGs) in which each child lived. These are administrative organizations of the UK National Health Service, responsible for providing prevention programs and health care services for areas with populations of about 100,000 residents.

Results

The total number of 5-year-old children on the school register in Chester and Ellesmere Port was 2,004. Of these, 1,840 (91.8%) children were available for clinical examination on the day of the survey. Two schools refused to provide the home addresses of children, so questionnaires could not be mailed to the parents of this group of subjects (N=64). Children attending these two schools therefore were omitted from the questionnaire survey. This left a total of 1,776 children who had a clinical examination and whose parents also received a questionnaire through the post. From this denominator population, 1,437 questionnaires were returned, a response rate of 80.9 percent.

The mean dmft of the total population was 1.49, which was 17.3 percent more than responders (1.27). The mean dmft of the respondents to the first mailing of the questionnaire was 1.16, a difference of 28.4 percent from that of the total population. However, the dmft of the nonresponders was 2.41, some 89.7 percent more than that of the responding population.

Table 1 shows the response by mailing stage. It also shows mean dmft, mean Jarman and Townsend values, and the number and percentage of male subjects by stage and for the nonresponders. The majority of responses (*N*=1,058; 59.6% of the total, and 73.6% of all responses) were received in answer to the first mailing stage. The number of responses tailed off with each successive stage. There were no substantial differences in the sex distributions by stage. There were, however, large differences in both dmft and the mean Jarman and Townsend scores between the three stages and with nonresponders. All three of these variables showed a significant linear trend, with the lowest levels of disease and deprivation found in responders to the first stage. Values successively increased with each stage, but the highest levels of disease and deprivation were found in nonresponders. There was a significant correlation (Spearman's rho, $P<.001$) between dmft and mailing stage (nonresponders included as a fourth data point). There were also significant correlations between both mean Jarman (Spearman's rho, $P<.001$) and Townsend (Spearman's rho, P.001) values and the mailing stage. Table 2 shows the percentage of children judged by their parents to be anxious about visiting the dental surgery at each stage. There was a significant ($P<.05$) linear relationship, with parental reported anxiety increasing with each successive stage.

Figure 1 shows a scatter plot of cumulative dmft by cumulative response rate in the responding population (after Hochstim), whereas Figure 2 shows a scatter plot of dmft by mailing stage. Both plots show an extrapolated regression line and 95 percent

TABLE 1
Mean dmft, Jarman and Townsend Scores with Standard Deviations and Sex (*N* and % of males) by Mailing State and for Nonresponders

Response Stage	*N* (%)	Mean dmft (SD)	Mean Jarman Score (SD)	Mean Townsend Score (SD)	Sex: Males *N* (%)
Stage 1	1,058 (59.6)	1.16 (2.49)	–2.57 (17.95)	–0.34 (3.81)	559 (52.8)
Stage 2	263 (14.8)	1.52 (2.66)	0.89 (18.40)	0.49 (3.88)	136 (51.7)
Stage 3	116 (6.5)	1.74 (2.58)	5.06 (19.68)	1.50 (4.26)	62 (53.4)
Nonresponders	339 (19.1)	2.41 (3.18)	8.01 (18.64)	2.03 (4.18)	175 (52.5)
Total	1,776	1.49 (2.71)	0.57 (18.73)	0.36 (4.02)	932 (52.5)
P		<.001*	<.001*	<.001*	.73†

*Spearman's rank correlation.
†Chi-square test for linear trend.

TABLE 2
Number and Percentage of Children with Parentally Reported Dental Anxiety According to Questionnaire Response Stage (Responding Population only *N*=1,405)

	Parental Reported Child Anxiety		Total
	Not Anxious *N* (Row %)	Anxious *N* (Row %)	*N* (Column %)
Response stage with missing school and nonresponders			
Stage 1	944 (90.33)	101 (9.67)	1,045 (74.38)
Stage 2	221 (87.35)	32 (12.65)	253 (18.01)
Stage 3	89 (83.18)	18 (16.82)	107 (7.62)
Total	1,254 (89.25)	151 (10.75)	1,405

Chi-square test for linear trend value=6.285; df=1; $P<.05$.

TABLE 3
Regression Coefficients, Standard Errors, Constant, and *P*-values from 6 Bivariate Linear Regression Models Fitted for Dependent Variables dmft and Parentally Reported Anxiety and Independent Variables Jarman and Townsend Scores, and Questionnaire Response Stage and Cumulative Percent of Responders

Dependent Variable	Independent Variable	β	SE	Constant	*P*-value
dmft of responding subjects	Jarman score	0.023	0.004	1.301	<.001
dmft of responding subjects	Townsend score	0.120	0.017	1.275	<.001
dmft of stage	Questionnaire stage	0.293	0.044	0.889	.77
Cumulative dmft	Cumulative % of responders	0.005	<0.001	0.855	.76
Cumulative % anxiety	Cumulative % of responders	0.049	0.009	6.733	.78
% anxiety at each stage	Questionnaire stage	3.575	0.344	5.879	.77

confidence intervals. Table 3 presents the results of bivariate regression analyses (nonresponders were excluded from the analyses) for:

- dmft of individual subjects (dependent variable) and Jarman score (independent variable),
- dmft of individual subjects (dependent variable) and Townsend score (independent variable),
- cumulative dmft (dependent variable) and cumulative percentage of the response rate (independent variable),
- dmft of each stage (dependent variable) and response stage (independent variable),
- cumulative anxiety (dependent variable) and cumulative percentage of the response rate (independent variable), and
- percentage of anxiety at each stage (dependent variable) and response stage (independent variable).

Highly significant linear relationships were demonstrated between the dmft of individuals and both their Jarman and Townsend scores, but for all of the other sets of variables the relationships were nonsignificant. The regression coefficients and constants were used to calculate estimated values for nonresponders and for revised whole population figures.

Table 4 explains the methodology applied, using Super Profiles Lifestyle groups as an example, to produce an adjusted dmft value for the whole population by applying mean dmft scores for the Jarman and Townsend deciles, and Lifestyle groups for the responding population to the same categories in the nonresponding population. Table 5 compares the adjusted whole population dmft values using the various estimating methodologies with the observed values for the whole population and for responders only. The methodology regressing dmft at each stage against mailing stage produced a much higher estimate for the dmft of the nonresponding population (2.06) and the most accurate adjusted value for dmft (1.42) compared to observed value (1.49). The value produced by Hochstim's method (regressing cumulative dmft against cumulative percent of responding population) produced the least accurate estimate (dmft=1.29). When the stage method was used to produce estimates for parentally measured anxiety, the estimate for nonresponders was again much higher than that produced by Hochstim's method (20.18% vs 11.63%), leaving a difference of 1.79 percent in the adjusted prevalence values for the whole population (12.68% vs 10.89%)

The two area measures of socioeconomic status indicators produced nearly identical values depending on

FIGURE 1
Scatter Plot of Cumulative dmft by Cumulative Percentage Response at Each Mailing Stage with Regression Line and 95% Confidence Intervals

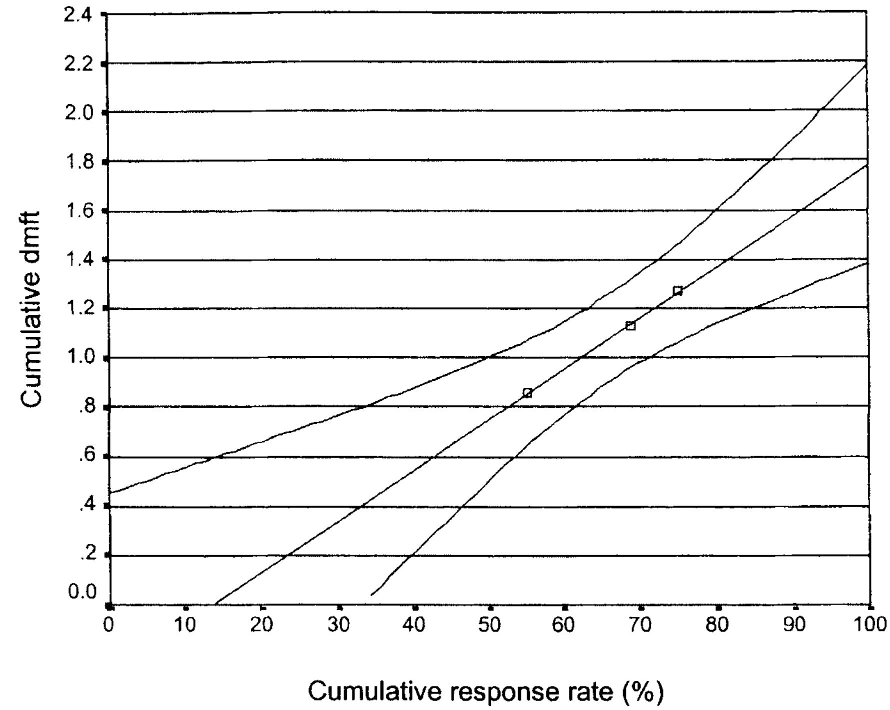

FIGURE 2
Scatter Plot of dmft by Mailing Stage with Regression Line and 95% Confidence Intervals

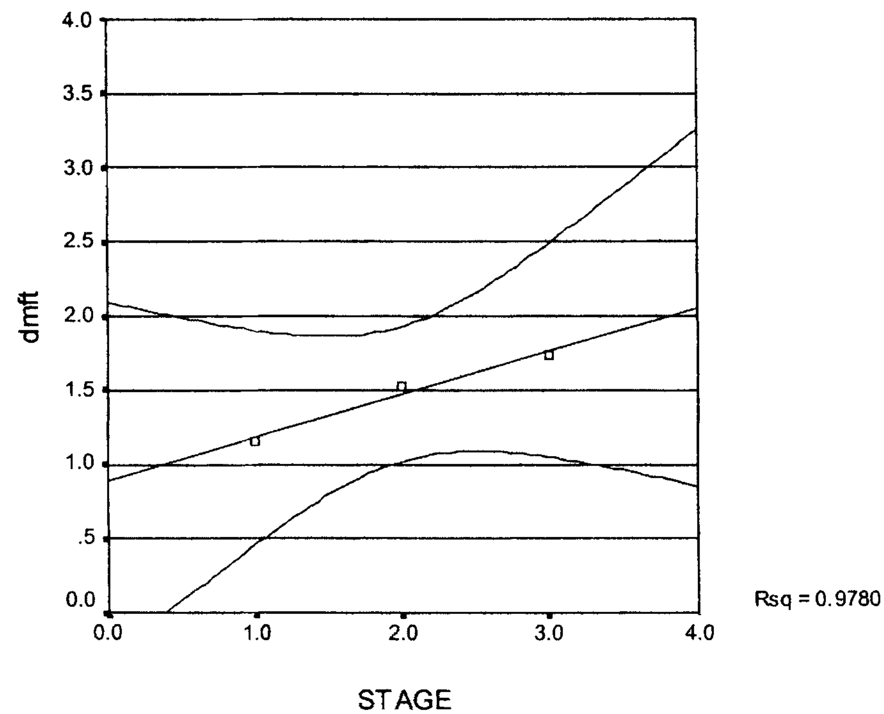

TABLE 4
Calculations to Produce Adjusted Population Estimate for dmft by Applying Mean dmft for Super Profiles Lifestyle Groups from Responding Population to Number of Subjects in Each Super Profiles Lifestyle Group in Nonresponding Population

Lifestyle Groups	Mean dmft Calculated from Responders	*N* of Nonresponders in Each Group	dmft * *N* Nonresponders	Adjusted dmft of Nonresponders
1	0.74	18	13.35	
2	0.84	17	14.20	
3	0.92	39	35.75	
4	1.34	57	76.66	
5	0.72	9	6.47	
6	1.26	2	2.51	
7	0.95	25	23.81	
8	1.87	52	97.28	
9	2.20	37	81.22	
10	2.02	78	157.53	
11	0.33	1	0.33	
Total	1.27	335	508.79	1.52
	dmft	*N*	dmft * *N*	Adjusted dmft for Whole Pop.
Actual dmft of all responders	1.27	1,410	1,790.7	
Est. dmft of nonresponders	1.52	335	509.2	
Total		1,745†	2,299.9	1.32

†Super Profiles Lifestyle score could not be ascribed to 31 (1.7%) records.

the methodology used. Using regression, the Townsend and Jarman indicators both produced adjusted dmft values of 1.31. The methodology whereby responder socioeconomic status values were applied to the nonresponder population was the same (dmft=1.32), irrespective of the area measure used. There was almost no difference in accuracy compared to the figures obtained by the regression method.

Tables 6 and 7 demonstrate the effect of nonresponse bias on measuring health inequalities. Table 6 shows the dmft of Jarman quintiles for responders, nonresponders, and the whole population. In every quintile of the population the dmft of responders was less than that of nonresponders. Although the dmft values for each quintile was greater for the total population than for nonresponders, a different picture emerged when the range of dmft values were examined. The difference between the dmft of the most affluent and most deprived groups in responders and the whole population was very similar: 1.26 (61.7% difference) and 1.38 (60.3% difference), respectively. However, the difference between most affluent and most deprived groups in the nonresponders was much smaller (dmft=0.55, 19.4%).

Table 7 shows how the responding

TABLE 5
Actual dmft Values for Total Population and Responder Populations Compared with Corrected dmft Values for Whole Population Produced by Different Methodologies*

Methodology	dmft value
Observed dmft of	
—Responding population	1.27
—Nonresponding population	2.41
—Whole population	1.49
Estimated dmft for whole population produced by	
—Extrapolating data from dmft at each mailing stage	1.42
—Regressing cumulative dmft against cumulative % of responding population	1.29
—Relationship between dmft and Jarman scores—estimated by regression	1.31
—Relationship between dmft and Townsend scores—estimated by regression	1.31
—Applying dmft values of Jarman deciles of responding population to number of subjects in each decile in nonresponding population	1.32
—Applying dmft values of Townsend deciles of responding population to number of subjects in each decile in nonresponding population	1.32
—Applying dmft values of Super Profiles Lifestyle groups of responding population to number of subjects in each decile in nonresponding population	1.32
Estimated prevalence of parentally assessed anxiety for whole population produced by	12.68
—Extrapolating data from prevalence scores at each mailing stage	
—Regressing cumulative percentage of anxiety against cumulative percent of the responding population	10.89

*Whole population dental anxiety prevalence estimates produced by two methodologies also are shown.

TABLE 6
dmft and Standard Deviations for Townsend Quintiles in Responding, Nonresponding Populations, and Total Population

DMFT Quintiles of Townsend	Responders		Nonresponders		All	
	dmft	SD	dmft	SD	dmft	SD
1 (affluent)	0.78	1.80	1.85	2.28	0.91	1.90
2	0.86	2.07	1.74	2.99	0.95	2.20
3	1.22	2.48	2.75	3.45	1.51	2.75
4	1.64	2.79	2.07	2.85	1.73	2.81
5 (deprived)	2.04	3.27	2.83	3.54	2.29	3.38
Total	1.27	2.54	2.40	3.19	1.49	2.71

TABLE 7
Number and Percentage of Responders, Nonresponders, and Total Population by Primary Care Group of Residence*

Primary Care Group	Responders *N* (%)	Nonresponders *N* (%)	All *N* (%)
Cheshire rural	217 (15.67)	27 (8.31)	244 (14.27)
Chester City	674 (48.66)	146 (44.92)	820 (47.95)
Ellesmere Port & Neston	494 (35.67)	152 (46.77)	646 (37.78)
Total	1,385	325	1,710

*Analysis restricted to residents of Cheshire Rural, Chester City, and Ellesmere Port and Neston in the study population (*N*=1,701).

and nonresponding populations differ by area of residence. A much larger percentage of nonresponders lived in the more deprived Ellesmere Port and Neston PCG (*N*=152, 46.77%) compared to responders (*N*=494, 35.67%). However, when comparing nonresponders with the whole population, the percentage difference of subjects living in Ellesmere Port and Neston PCG was much smaller, 35.67 percent and 37.78 percent, respectively.

Discussion

The high participation rate of the clinical survey was due to the use of passive consent, which is the norm for the regular UK National Health Service epidemiologic surveys. The response to the questionnaire survey was high (80.9%) and would be acceptable for publication in many peer-reviewed journals. Yet the results show that even with an acceptable response rate, nonresponse bias would have had an effect on the results obtained and conclusions drawn, and one would expect the effects to be magnified with a lower response rate. Conventional wisdom suggests that a response rate of at least 80 percent is needed to reduce the possibility of nonresponse bias producing significant errors in study results (15).

This study and others (6,16,17) demonstrate that using multiple stages in the postal distribution process of questionnaires can significantly increase response rates. This methodology has the added advantage of providing a means of detecting and correcting for nonresponse bias. There was a linear relationship between stage of response (including nonresponders as a fourth data point) and socioeconomic status. This lends credence to the hypothesis that late responders to a questionnaire are more similar to nonresponders than early responders (8). It also demonstrates the strong association between socioeconomic status and nonresponse to mail surveys.

The large difference in dmft between responders and nonresponders also shows how different responders and nonresponders to questionnaires can be in terms of health. In this study the disease experience of nonresponders was 89.7 percent greater than responders. This had a relatively small effect on the values derived for the total population (1.27 vs 1.49, 17.3% difference). One would have expected it to have a much greater effect on the measurement of health inequalities. The results in this respect require careful consideration.

The dmft of nonresponders across all of the social strata was greater than responders, suggesting that, regardless of socioeconomic status, nonresponders have different health-related behaviors than responders. There was a near identical range in dmft values between most deprived and most affluent groups between the responders and total population. The nonresponse bias had little effect on the relative differences of dmft in affluent and deprived groups. Therefore, on this analysis alone one would question the impact of nonresponse bias on the measurement of health inequalities. However, when the geographical location of nonresponders was identified, a much larger percentage of nonresponders, with greater health needs, lived in Ellesmere Port and Neston PCG. Therefore, if the results from responders to questionnaires were to be used to help shape health policy and allocate health resources, this would result in an unfairly reduced share being given to the health organizations containing the most needy residents.

In this study, strong evidence of nonresponse bias was detected for two health outcome variables. However, this does not mean a low response rate automatically indicates nonresponse bias is present. Many studies in the literature suggest that a low response rate may not necessarily compromise the results of descriptive studies (6,7,17,18). What this study does demonstrate is the need for researchers to check for the presence of nonresponse bias. This is probably best done by looking at the relationship between response stage (plus nonresponders) and socioeconomic status using an area-based proxy measure of deprivation. In the United Kingdom it is possible to quickly ascribe socioeconomic status values to individuals by reference to their postcode. However, this level of refinement may not be available in other countries and other area-related proxy measures of socioeconomic status may need to be used or developed. This approach seems intuitively sensible, as most health and health services variables are closely related to socioeconomic status. The example used in this study, tooth decay, has been shown time and again to have a close relationship with deprivation (19,20,21). The choice of the area measure of socioeconomic measure used to detect the presence of nonresponse bias would seem to be of secondary importance because this study, like others (22,23), has shown little difference in the performance of the commonly used deprivation indicators. Ecological fallacy, the assumption that all individuals living in a small area have the same socioeconomic status, seemed to have little influence on the results obtained as the Lifestyle groups are based on the much smaller and homogeneous populations of EDs rather than the electoral ward-based Jarman and Townsend measures.

If there is no linear trend for the outcome variable of interest across the mailing stages and/or between the variable and a measure of socioeconomic status, one can assume that nonresponse bias is not present to any significant degree and no correction is necessary. However, if adjustment were to be necessary, it would seem from this study that response stage, rather than Hochstim's method or the relationship with socioeconomic status, provides the most accurate adjusted value. This was a surprising finding, given that only three data points were available to construct a regression model. The small number of data points and the resultant lack of power probably account for the nonsignificant relationships between dmft and response stage and also between cumulative dmft and cumulative percent response and the very wide confidence intervals in Figures 1 and 2. The accuracy of using the postal stage methodology may not be replicated in other studies, as the relationship between response stage and the outcome variable of interest may be specific for each variable. In this case, the relationship between socioeconomic status and the variable of interest may provide more accurate adjusted values. Therefore, all variables of interest should be independently checked for linear trends using both stage of response and socioeconomic status, as there is no guarantee that if some variables are found to be affected by nonresponse bias all variables in the data will be likewise affected. There is a need to ensure that any bias detected is consistent throughout the data.

In conclusion, simple and effective methods to detect and correct for nonresponse bias have been demonstrated. Even with an "acceptable" response rate to questionnaire studies, nonresponse bias nevertheless may be present and researchers should present the results of analyses to detect nonresponse bias when publishing questionnaire studies. Detection and correction of nonresponse bias should use two different methodologies to compare outcomes. Likewise, the effect on health inequalities should be examined by looking at absolute and relative differences in socioeconomic status and differences according to the area of residence of the subjects. Such an approach would make the reporting of research findings from postal questionnaires more accurate and more credible.

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