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Special Article

The Quality of Modern Cross-Sectional Ecologic Studies: A Bibliometric Review

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The ecologic study design is routinely used by epidemiologists in spite of its limitations. It is presently unknown how well the challenges of the design are dealt with in epidemiologic research. The purpose of this bibliometric review was to critically evaluate the characteristics, statistical methods, and reporting of results of modern cross-sectional ecologic papers. A search through 6 major epidemiology journals identified all cross-sectional ecologic studies published since January 1, 2000. A total of 125 articles met the inclusion requirements and were assessed via common evaluative criteria. It was found that a considerable number of cross-sectional ecologic studies use unreliable methods or contain statistical oversights; most investigators who adjusted their outcomes for age or sex did so improperly (64%), statistical validity was a potential issue for 20% of regression models, and simple linear regression was the most common analytic approach (31%). Many authors omitted important information when discussing the ecologic nature of their study (31%), the choice of study design (58%), and the susceptibility of their research to the ecological fallacy (49%). These results suggest that there is a need for an international set of guidelines that standardizes reporting on ecologic studies. Additionally, greater attention should be given to the relevant biostatistical literature.

cross-sectional studies; ecological models; epidemiologic methods; research design; review

The ecologic study design is one of the oldest in epidemiology. Its susceptibility to bias has been well known since Robinson (1) popularized the concept of the ‘‘ecological fallacy’’ in 1950, although the potential incongruence between group and individual associations was studied by Thorndike (2) as far back as 1939. Since then, there has been significant progress in discovering the many avenues by which ecologic bias may manifest. It is now well documented that the relations between individual- and group-level inferences are often complex, and sometimes even counterintuitive. In spite of this wealth of knowledge, the ecologic design and its fallacy often remain misunderstood (3).

Limitations of the ecologic design have not prevented its use. This is especially true in community health research, where investigators are often interested in both individual-level and ecologic associations with the study outcome. The appeal of ecologic studies reflects interest in collecting information beyond the level of individuals by incorporating aggregate variables as well as those without individual-level analogs. Additionally, ecologic studies do not require information on individuals within groups, making such studies easier to conduct and less expensive. In recent articles, authors have defended the ecologic design and nonindividualistic perspectives in general (4–6), arguing that ecologic analyses need not always be relegated to the role of a poor approximation of other designs, since legitimate insights may exist at the group level. Shifts in the conception of causality and the means by which it exerts itself have also helped in asserting the value of ecologic studies. For these reasons and others, ecologic studies continue to be performed in epidemiology.

Given that ecologic analyses are often misunderstood yet continue to be used, it is important to assess the quality of the literature. Insofar as we are aware, there have been no reviews of ecologic studies. Our objective in this bibliometric review was to address this need by evaluating how well modern ecologic studies are designed, analyzed, and reported in epidemiology. Emphasis was placed on statistical methods and the clarity of reporting. All articles were collected from 6 major epidemiology journals, with attention restricted to cross-sectional etiologic studies. A total of 125 articles published between the years 2000 and 2009 met the inclusion

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requirements and were analyzed according to common evaluative criteria.

MATERIALS AND METHODS

Journal selection

Articles published in 6 high-impact epidemiology journals were selected to collectively represent the discipline. The following journals were chosen: the *American Journal of Epidemiology*, the *Annals of Epidemiology*, *Epidemiology*, the *International Journal of Epidemiology*, the *Journal of Clinical Epidemiology*, and the *Journal of Epidemiology and Community Health*. Although many epidemiologic articles are published outside of pure epidemiology journals, it was nevertheless felt that these 6 would provide a useful core sample for the purposes of the review. Articles published between 2000 and 2009 were included, reflecting our interest in recent applications of ecologic studies.

Search method

Articles were found by reading through each issue of the selected journals for the time period January 1, 2000, through December 31, 2009. An alternative approach would have been to conduct computer searches of databases such as MEDLINE with the use of strategic keywords or Medical Subject Headings. While this may be an adequate means of obtaining data on many types of studies, the ecologic design is so varied in its applications that some researchers may use it unknowingly or without including the kinds of keywords that would be found by search engines or database categorization. Thus, a manual search was performed.

Inclusion and exclusion criteria

The focus of this review was on etiologic cross-sectional studies. Therefore, each study had to employ a cross-sectional design. Ecologic studies using temporal, spatiotemporal, or case-control designs were excluded from the review. For example, Loomis et al. (7) analyzed workplaces to determine risk characteristics for homicide. Workplaces were selected on the basis of whether or not a homicide had taken place there, which made the study design case-control, not cross-sectional.

Additionally, investigators in each study needed to present original research of an etiologic nature. Consequently, spatial descriptive studies or articles that discussed ecologic methodology were excluded. An article did not need to be entirely ecologic to be included in the review, as long as the study's ecologic aspects met the inclusion criteria. Thus, articles with multilevel or individual-level components in addition to ecologic analyses were included as well.

Evaluation criteria

Each article was evaluated according to 3 broad themes: study design, statistical methodology and practices, and quality of reporting.

Study design and focus. We attempted to obtain an impression of the scope of each study, its nontechnical methods, and its focus. Aspects of study design which were analyzed included sample size, given by the number of ecologic units; the level of aggregation at which the units existed, grouped from smallest to largest as census tracts or neighborhoods, municipalities, municipal areas or counties, states or provinces, and nations; whether the inferences were made at the group level or the individual level; and whether the ecologic units were explicitly chosen to suit the hypothesis or were seemingly motivated by convenience or necessity. This last criterion was deemed relevant because many ecologic analyses may be limited by the availability of preexisting aggregate data.

We also recorded the primary outcome for each study according to a set of broad classifications. Whenever possible, outcomes were given one of the following categorizations, which were motivated by the literature itself: cancer, cardiovascular disease, respiratory disease, chronic disease, infectious disease, mortality, suicide or self-harm, and criminal activity. Often, a given study had more than one outcome and thus more than one classification. In this case, all outcomes were recorded.

Statistical methodology. Four aspects of statistical methodology were evaluated: analytic methods, the number of ecologic units relative to the number of regression coefficients modeled, whether any consideration was given to spatial dependence, and methods used to account for confounders. Whenever possible, analytic methods used were grouped by topic. The notation of statistical methodology was intended to provide a measure of the analytical sophistication, diversity, and propriety of current ecologic studies. It was especially important to note the prevalence of simple methods such as ordinary least squares regression and Pearson correlation, since these have well-known limitations in ecologic settings (8, 9).

The statistical validity of each regression model was also observed. Simulation studies have indicated that the validity of statistical inferences is probably compromised when the ratio of covariates to observations or events exceeds a certain threshold (10). The most common recommendation is to have a minimum of 10 observations per covariate, though this may be too conservative for some models (11). Therefore, for each regression analysis, we recorded whether there were fewer than 10 ecologic units per covariate, 10–20 units per covariate, or more than 20 units per covariate. This criterion was developed in the context of individual-level analyses for independent outcomes. It probably only holds approximately for ecologic studies, as event rates and cluster size are likely to play a role in the validity of statistical inferences.

Spatial autocorrelation is a potential concern for many ecologic studies, since units are often aggregated over spatial regions such as contiguous census tracts. The concern is that the omission of spatial effects may cause a loss of information that could otherwise improve parameter estimation, as indicated by recent simulation studies (12, 13). Indeed, explicitly modeling spatial variability may help account for bias when the spatial variation of the covariate is similar to that of disease risk and location itself acts as a confounder (14). However, it is sometimes difficult to know which approaches are based on reasonable assumptions for a given situation, since assumptions are often untestable (15). Nonetheless, we recorded the number of studies accounting for spatial effects

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to report the habits of researchers and the sophistication of the literature.

The final methodological criterion investigated the use of covariate adjustment. Although more complex, confounding may still occur at the ecologic level, and under certain conditions it can be accounted for by the inclusion of covariates. Similarly, we sought to determine whether the covariates were themselves properly adjusted when regressed upon adjusted outcomes; Rosenbaum and Rubin (16) point out that aggregate studies commonly regress age- or sex-standardized outcomes on unstandardized predictors, which may lead to bias. They recommend that regression analyses with group-level data incorporate either adjusted covariates or crude covariates along with moments of the population distribution for the confounder (such as mean age). We report how often this is done in practice.

Quality of reporting. The complexities of the ecologic design are such that in every ecologic study, investigators should justify their choice of study design and present their results in a transparent fashion. Each article should be written so that even readers unfamiliar with the ecological fallacy are mindful of its potential. To this end, we searched each paper to see whether the authors mentioned one of the keywords "ecologic," "ecological," or "aggregate" in their article, excluding references. This was intended to estimate the proportion of authors who clearly informed the reader of the study design. We also looked to see whether the authors explicitly justified an ecologic analysis. A justification allows readers to be informed of the rationale for the choice of design and to decide for themselves whether an ecologic analysis was truly warranted. It was not deemed essential for the justification to mention any of the above keywords as long as the authors presented a clear explanation.

We also recorded whether the authors sufficiently cautioned readers, in interpreting their results, against making heedless individual-level inferences, preferably with the use of terms such as "ecological fallacy" or "cross-level bias." The statement did not need to be elaborate. It merely needed to point out that the results were not necessarily applicable to different levels of aggregation.

None of the above criteria for reporting are present in the STROBE guidelines for the reporting of observational studies in epidemiology (17), which presently omit ecologic studies.

RESULTS

Our search yielded a total of 125 cross-sectional ecologic papers. Table 1 shows their distribution by journal and year of publication. From Table 1, it can be seen that the number of published cross-sectional studies has remained relatively stable over the past decade.

Study design and focus

The most common area of focus was cancer, which comprised 16% of all primary outcomes. Other research areas such as mortality, chronic disease, and cardiovascular disease followed behind, representing 14%, 13%, and 10% of total analyses, respectively. Infectious and respiratory diseases

Table 1. Numbers of Cross-Sectional Ecologic Studies Included in a Bibliometric Review, by Journal and Period, 2000–2010

Journal	2000–2002	2003–2005	2006–2009	Total
American Journal of Epidemiology	4	3	5	12
Annals of Epidemiology	2	4	6	12
Epidemiology	5	0	7	12
International Journal of Epidemiology	12	9	7	28
Journal of Clinical Epidemiology	1	1	2	4
Journal of Epidemiology and Community Health	14	20	23	57
Total	38	37	50	125

Table 2. Results for Study Design and Focus Criteria in a Bibliometric Review of Ecologic Studies, 2000–2010

Evaluation Criterion	Observed Frequency (n = 125)	
	No.	%
Sample size		
Median	70	
Maximum	~200,000	
Minimum	8	
Level of data aggregation		
Census tract or neighborhood	48	38
City or town	11	9
County	22	18
Province or state	15	12
Nation or nation-cluster	25	20
Other	4	3
Level of inference		
Individual	43	34
Ecologic	34	27
Unclear	48	38
Prespecification of ecologic units (yes)	22	18
Classification of primary outcome(s)[a]		
Violent crime	8	6
Suicide and self-harm	9	7
Respiratory disease	10	8
Infectious disease	11	9
Cardiovascular disease	13	10
Chronic disease	16	13
Mortality	18	14
Cancer	20	16
Other	26	21

[a] Total exceeds 125 because categories were not mutually exclusive.

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Table 3. Results for Statistical Methodology Criteria in a Bibliometric Review of Ecologic Studies, 2000–2010

Evaluation Criterion	Observed Frequency (n = 125)	
	No.	%
Analytic methodology[a]		
Ordinary least squares regression	47	31
Poisson regression	20	13
Weighted linear regression	18	12
Nonparametric methods	12	8
Pearson or Spearman correlations	12	8
Bayesian models	12	8
Logistic regression	7	5
Negative binomial regression	7	5
Other	18	12
Validity of regression[a]		
<10 units per covariate	27	20
10–20 units per covariate	48	36
>20 units per covariate	43	32
Not applicable	11	8
Unclear	5	4
Use of covariates (yes)	92	74
Spatial analysis (yes)	26	21
Did not properly adjust for covariates (n = 36)	23	64

[a] Total exceeds 125 because categories were not mutually exclusive.

comprised 9% and 8% of all outcomes, respectively; suicide and self-harm accounted for another 7%; and criminal activity such as homicide accounted for 6% (Table 2). Twenty-six analyses did not fall into one of the above broad subclassifications, with outcomes ranging from pollution exposure to regional disparity.

It appears that much cross-sectional research potentially has its data dictated by either the convenience or the necessity of using preexisting information. We suspect that this is the case after observing that only in 22 studies (18%) did authors implicitly or explicitly justify their choice of ecologic units. In a few cases, the units of aggregation were constructed specifically for the study.

Potentially, investigators in many other studies simply used what was available. With regard to level of aggregation, many studies utilized small areas. Ecologic units aggregated approximately at the level of census tracts were by far the most numerous, being the observational units for 48 studies (38%). Large international studies were the second most prevalent, being the focus of 25 studies (20%). All other levels of aggregation were present as follows: towns and cities, 9%; counties (which include not only cities but their contiguous areas as well), 18%; and states or provinces, 12%. Four studies could not have their ecologic units classified as above, either because the units were disparate areas specifically constructed for the study or because they were nonspatial.

Table 4. Results for Quality-of-Reporting Criteria in a Bibliometric Review of Ecologic Studies, 2000–2010

Evaluation Criterion	Observed Frequency (n = 125)	
	No.	%
Statement of study design (yes)	86	69
Justification of study design (yes)	52	42
Discussion of cross-level bias		
Yes	55	44
Not applicable	9	7

Many investigators intended their inferences to be applied at the individual level. Of the 125 articles in the review, 43 (34%) clearly had conclusions or hypotheses concerned with individual-level risks and outcomes. In 34 studies, authors unambiguously tailored their discussions to group-level inferences (27%). However, this should be taken lightly, since a lack of clarity on the part of 48 studies (38%) prevented us from confidently determining their intended levels of inference. The vast majority of outcomes were aggregate in nature (97%), meaning they had individual-level analogs which could apply to units within groups. Nonaggregate outcomes included measures such as regional socioeconomic inequality and governmental health-care expenditures.

Sample sizes ranged from very small to extremely large. The minimum sample size was 8 ecologic units, and the maximum was approximately 200,000. The median sample size was 70. Fifty-four percent of studies relied on fewer than 100 observations.

Quality of statistical methods and practices

The literature is highly diverse in its methodological complexity. Nevertheless, there were notable preferences. The most common approach was to use either ordinary least squares regression or Poisson regression, methods that were employed in 47 and 20 analyses, respectively (Table 3). Weighted linear regression was the third most common approach, being used in 18 analyses. Nonparametric approaches and simple Pearson or Spearman correlations each accounted for 12 analyses. The more complex approaches of Bayesian analytic methods, logistic regression, and negative binomial regression appeared in 12, 7, and 7 articles, respectively. An additional 18 analyses did not fall into any of these categories, employing disparate techniques such as sophisticated geospatial methods, spatial autoregressive models, and simple calculations of standardized mortality ratios. Note that these counts do not refer to the number of studies but rather to the number of analyses, since investigators may have used more than 1 method. In terms of covariate adjustment, 92 studies obtained adjusted results, either by stratifying the analyses or using additional covariates in the models. Unfortunately, in 23 of 36 papers, the investigators failed to adjust covariates for age or sex when the outcomes had been standardized for these potential confounders. Thus, it would appear that in over half of all studies using standardized outcomes, investigators were at risk of publishing biased inferences.

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There was mixed performance with regard to the statistical validity of regression models. Although we were unable to determine the ratio of ecologic units to predictor variables for 5 studies, we found that of the 109 studies with regression models, 27 had fewer than 10 units per covariate. Forty-eight analyses had 10–20 units per covariate, and 43 regression analyses had more than 20.

One-fifth of all studies included some investigation of spatial effects. Techniques such as spatially autocorrelated regression models and spatial scan statistics appeared to be the most common. Some of these techniques merely detect and describe spatial clustering, while others seek to incorporate spatial data into effect measure estimation.

Quality of reporting

Of the papers reviewed, authors in 86 (69%) clearly specified their study design by mentioning "ecologic," "ecological," or "aggregate" at some point in the main body of their work in a clear and relevant fashion (Table 4). Only 52 studies (42%) adequately and explicitly justified an ecologic analysis, while the other articles did not provide any rationale whatsoever as to why the design was either necessary or desirable. Perhaps most significantly, we discovered that in the majority of the reviewed studies, investigators did not sufficiently inform the reader about the possibility of cross-level bias; in 55 articles (44%), authors tempered their results in some fashion, whereas in 61 (49%) they did not. For 9 articles this criterion did not apply, either because the ecologic investigations appeared alongside multilevel analyses or because the predictors were entirely group-level in nature, thereby precluding individual-level interpretations.

DISCUSSION

Ecologic research in epidemiology is extremely diverse in its applications and sophistication. However, it appears that a combination of methodological limitations, apparent dependence on preexisting data, and insufficient reporting has compromised the quality and clarity of some articles.

Broadly speaking, the distribution of the reviewed studies could best be described as bimodal. Many investigators performed elementary analyses coupled with unclear, insufficient reporting. At the same time, a significant number of studies employed analyses appropriately suited to the study design and presented the results in a model fashion. In between these extremes, many studies were adequate with respect to 1 or 2 of the 3 fundamentals, only to perform unsatisfactorily in another.

In terms of statistical methodology, researchers must better heed many of the important technical results published in the biostatistical and epidemiologic literature. More attention needs to be paid to proper covariate adjustment and the validity of regression models. It is also apparent that linear regression and simple correlation coefficients have become the default techniques for many ecologic studies. Given their documented susceptibility to ecologic bias, this may indicate that some technical details of group-level analysis remain unknown or misunderstood. While the validity of these approaches must be decided on a case-by-case basis, the fact that over half of analyses rely on them suggests that ecologic researchers depend too often on techniques of uncertain reliability.

The area of greatest concern in this review was the quality of reporting. The results showed a lack of important information when it came to stating the origins of the data, the intended level of inference, the nature of the study design, and the study's limitations. The sensitive and diverse nature of ecologic analyses makes it essential that readers from all backgrounds be sufficiently informed. Too often, authors seemingly assumed that their choice of study design was self-evident, did not require justification, and provided unambiguous results.

For the selection of ecologic groups, the ideal is that in every study investigators choose their units according to the specific causal constructs of their research. However, as Morgenstern (18) stated, ecologic studies are often made possible by preexisting data. Since few investigators made their selection criteria known, there is often reason to wonder how or why the data were chosen. The high prevalence of studies conducted at the census tract and national levels may be a result of the fact that easily available information tends to exist at these scales of aggregation. In future papers, researchers should state why their particular units and levels of aggregation were suitable for the hypothesis at hand.

In accordance with recommendations made by von Elm et al. (17), we submit that there is presently a need for a set of guidelines to standardize the reporting of results from ecologic studies. Many of the concerns we identified could be attenuated or prevented altogether if such a document were published. Providing a set of guidelines that not only lists detailed criteria but also explains their importance and the potential consequences of their neglect may emphasize their relevance to the research community. From the results of this review, it is clear that the cross-sectional ecologic design continues to be an important approach relied upon by epidemiologists and public health researchers, and therefore it would be worthwhile to augment the STROBE document (17) with recommendations for the reporting of ecologic findings.

In Appendix Table 1, we list 9 items that could serve as a useful beginning for updating the STROBE document. For ease of reference, the table has the same headings, titles, and numberings as the STROBE document itself (17). Ideally, future discussions on this topic by others in the epidemiology community would provide further critiques of and refinements to this list.

Difficulties in correctly designing, analyzing, and reporting results are not unique to ecologic studies. Analogous methodological errors have been reported for both observational studies (19) and randomized trials (20). There may be some reason for optimism, since Hopewell et al. (20) did find some improvement in the reporting of randomized trials following release of the CONSORT statement (21). This provides further motivation for developing reporting guidelines for ecologic studies.

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REFERENCES

1. Robinson WS. Ecological correlations and the behavior of individuals. *Am Sociol Rev*. 1950;15(3):351–357.
2. Thorndike EL. On the fallacy of imputing the correlations found for groups to the individuals or smaller groups composing them. *Am J Psychol*. 1939;52:122–124.
3. Greenland S, Robins J. Invited commentary: ecologic studies—biases, misconceptions, and counterexamples. *Am J Epidemiol*. 1994;139(8):747–760.
4. Tu JV, Ko DT. Ecological studies and cardiovascular outcomes research. *Circulation*. 2008;118(24):2588–2593.
5. Wakefield J. Ecologic studies revisited. *Annu Rev Public Health*. 2008;29(1):75–90.
6. March D, Susser E. The eco- in eco-epidemiology. *Int J Epidemiol*. 2006;35(6):1379–1383.
7. Loomis D, Wolf SH, Runyan CW, et al. Homicide on the job: workplace and community determinants. *Am J Epidemiol*. 2001;154(5):410–417.
8. Duncan OD, Cuzzort RP, Duncan B. *Statistical Geography: Problems in Analyzing Areal Data*. Glencoe, IL: The Free Press; 1961.
9. Greenland S, Morgenstern H. Ecological bias, confounding, and effect modification. *Int J Epidemiol*. 1989;18(1):269–274.
10. Babyak MA. What you see may not be what you get: a brief, nontechnical introduction to overfitting in regression-type models. *Psychosom Med*. 2004;66(3):411–421.
11. Vittinghoff E, McCulloch CE. Relaxing the rule of ten events per variable in logistic and Cox regression. *Am J Epidemiol*. 2007;165(6):710–718.
12. Anselin L, Cho W. Spatial effects and ecological inference. *Polit Anal*. 2002;10(3):276–297.
13. Haneuse S, Wakefield J. Ecological inference incorporating spatial effects. In: King G, Rosen O, Tanner MA, eds. *Ecological Inference: New Methodological Strategies*. New York, NY: Cambridge University Press; 2004:266–302.
14. Clayton DG, Bernardinelli L, Montomoli C. Spatial correlation in ecological analysis. *Int J Epidemiol*. 1993;22(6):1193–1202.
15. Wakefield J. Disease mapping and spatial regression with count data. *Biostatistics*. 2007;8(2):158–183.
16. Rosenbaum PR, Rubin DB. Difficulties with regression analyses of age-adjusted rates. *Biometrics*. 1984;40(2):437–443.
17. von Elm E, Altman DG, Egger M, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. STROBE Initiative. *BMJ*. 2007;335(7624):806–808.
18. Morgenstern H. Ecologic studies in epidemiology: concepts, principles, and methods. *Annu Rev Public Health*. 1995;16:61–81.
19. Papathanasiou AA, Zintzaras E. Assessing the quality of reporting of observational studies in cancer. *Ann Epidemiol*. 2010;20(1):67–73.
20. Hopewell S, Dutton S, Yu LM, et al. The quality of reports of randomised trials in 2000 and 2006: comparative study of articles indexed in PubMed. *BMJ*. 2010;340:c723. (doi:10.1136/bmj.c723).
21. Begg C, Cho M, Eastwood S, et al. Improving the quality of reporting of randomized controlled trials: the CONSORT statement. *JAMA*. 1996;276(8):637–639.

(Appendix follows)

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Appendix Table 1. Suggested Additions to the STROBE Document for Ecologic Reporting[a]

STROBE Section	Recommendation Addition(s)
Title and abstract	Indicate the study's design with a commonly used term in the title or abstract.
	Ecologic study—Use one of the following terms in your description: "ecological," "ecologic," or "aggregate."
Introduction	
Objectives	State specific objectives, including any prespecified hypotheses.
	Ecologic study—Specify the level(s) of inference to which your investigation is intended to apply.
Methods	
Study design	Present key elements of the study design early on in the paper.
	Ecologic study—Provide a rationale or justification for the design, taking your study objectives into account.
Participants	Ecologic study—Give the eligibility criteria for the ecologic units, as well as their sources and any sampling methods used. Provide a rationale for their selection. If the units were aggregated for the study, explain how this was done and the criteria by which they were constructed.
Discussion	
Limitations	Discuss limitations of the study, taking into account sources of potential bias or imprecision.
	Ecologic study—Provide a discussion that either informs the reader of the potential for cross-level bias or explains why it is not a possibility for your results and inferences.

Abbreviation: STROBE, Strengthening the Reporting of Observational Studies in Epidemiology.
[a] Patterned after the STROBE statement (17).

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