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Systematic review

The quality of published ecological papers in top journals

Naeemeh Shahdadi[1], **AliAkbar Haghdoost**[2*], **Naser Nasiri**[3]

[1]Social Determinants of Health Research Center, Institute for Futures Studies in Health, Kerman University of Medical Sciences, Kerman, Iran
[2]Modeling in Health Research Center, Institute for Futures Studies in Health, Kerman University of Medical Sciences, Kerman, Iran
[3]Department of Epidemiology and Biostatistics, School of Health, Jiroft University of Medical Sciences, Jiroft, Iran

*Corresponding Author: AliAkbar Haghdoost, Email: ahaghdoost@gmail.com

Abstract

Background: Ecological studies explore the relationships among variables in sub-populations, aiming to generate hypotheses; however, they are prone to errors. We explored two main types of errors in published ecological articles. These errors were "ecological fallacy" and "ignored lag time between exposure and outcome."

Methods: We reviewed the published ecological articles in 100 top medical and public health journals based on their impact factors in Scopus from January 2020 to December 2022. We found only 13 journals with at least one published ecological article (IF between 1.3 and 13.3).

Results: A total of 68 ecological articles were extracted and reviewed. Ecological fallacy was found in 23% of the 40 studies. Although ignored lag time should have been considered in 21% of the studies, only 36.0% of them mentioned it.

Conclusion: Despite the importance of ecological research, especially in understanding complex environmental and health-related issues, many studies failed to adequately address critical methodological factors such as ecological fallacy (EF) and ignored lag time (LT). Although most researchers are familiar with the strengths and weaknesses of ecological studies, they did not mention them and take them into account.

Keywords: Ecological study, Ecological fallacy, Ecological error, Cross-level bias, Lag time

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Introduction

An ecological study (ES) is a type of observational study (1), also called a correlational study. These studies are called ecological because researchers usually use geographic areas to define the unit of analysis (2). Ecological studies play a vital role in understanding the complex relationships between organisms and their environments. By examining interactions within ecosystems, these studies reveal how various species, including humans, influence and are affected by environmental factors (3).

These studies are used to monitor changes in a population over time (2). ESs often use data from large populations based on national and regional data such as cancer registry systems and hospital and climate data (4). This knowledge is crucial for developing sustainable conservation strategies, managing natural resources, and addressing global challenges such as climate change and biodiversity loss (5).

Ecological studies offer numerous advantages in understanding the natural world. They provide comprehensive insights into the interactions and dependencies among various species and their environments, helping to identify key factors that influence ecosystem health and stability. These studies are essential for informing conservation efforts and enabling scientists to develop effective strategies for protecting endangered species and habitats. Additionally, ecological research can predict the impacts of environmental changes, such as pollution or climate change, allowing for proactive management. Overall, ecological studies contribute to sustainable resource use and environmental preservation, making them invaluable for maintaining the planet's biodiversity and ecological balance. They are usually non-expensive, and implementation is convenient and straightforward (6, 7).

While ecological studies are valuable, they also come with certain drawbacks (2). One of these limitations is the ecological fallacy (EF), which may affect the conclusions of these studies significantly (4). This error occurs when the relationships among variables are measured at the group level, but their interpretation is at the individual level (7). Interpretations of the relationship between exposure and outcome are not the same at the personal and group levels; for example, the increase in the risk of breast cancer in a person exposed to twice the radium density is not similar to the risk in people working in a place with a similar

radium density (4).

As the data of ecological studies includes national surveys and hospital data usually collected for non-research aims, they may lead to confounding, reverse causality, and non-causal associations, partly because the exposure and outcome variables are usually measured in the same period, making it confusing to determine which one occurred first (2). Considering a reasonable lag time (LT) between the date of exposure and the date of outcomes helps researchers to estimate a more accurate and precise relationship (8). For example, it is more justified to assess the relationship between the level of smoking and the incidence of cancers among different countries with a lag time of 10 years or higher (2).

Due to the potential errors associated with ecological studies, such as ecological fallacy and lag time effects, these studies may produce biased or misleading results (7). Therefore, researchers must carefully consider these factors—specifically EF and LT errors—to avoid drawing inaccurate conclusions about individual-level relationships based on aggregate data. Recognizing these limitations is essential for enhancing the validity and reliability of ecological studies. In light of these considerations, our study aims to evaluate the quality, strengths, and weaknesses of published ESs in leading scientific journals.

Methodology

Selection of journals, articles, and data collection tools

Based on the journals' IF in Scopus, the top 100 journals in the medical and public health domains were selected. We searched the published papers for any type of ES between January 2020 and December 2022 and found 13 journals with at least one published ecological paper; the IF of these sub-group journals was between 1.3 and 13.3. Then, researchers read the full texts of the ESs and developed a quality assessment tool based on the study's objectives and key STROBE principles, as there was a lack of a suitable quality assessment tool for ecological studies. We used this tool to extract the required data from eligible studies.

Quality assessment and data extraction

Two of the authors assessed the quality of the papers and extracted the data. All disagreements were presented to the third author, and the final decisions were made by consensus. The quality of studies was reviewed based on a pre-defined checklist. The extracted data included the methodology and the research question of the papers, specifically, the risk of EF and the potential impact of LT error on the conclusion. In addition, the justification of authors on the impact of these two types of errors on their conclusion was recorded.

Analysis

After extracting the data, the main variables such as "did not use checklist designing and writing," "Did not mention the threat of ecological fallacy," "Lag time error was not a real concern," "Did not clearly state the type of study in the methodology," "Did not clearly state the type of study," "No explanation about the concept of ecological fallacy," "Ecological fallacy was not real concern," and "Did not discuss the potential risk of biases" were described. Also, STATA software was used for data analysis.

Results

Among 14,971 articles published in the reviewed journals, we found 68 ESs (0.45%). The highest number of published ecological articles ($n = 25$) was in the *Environmental Research Journal* (IF = 8.8). However, the highest and lowest relative frequencies of published ESs were in the *Cancer Epidemiology Journal* (IF = 2.89, 9 out of 478 articles, 1.88%) and the *Annals of Medicine and Surgery Journal* (IF = 1.34, 1 out of 2624 articles, 0.06%) (Table 1).

The title of only 57% (39 out of 68) of papers included the type of study. None of them, except one, used a standard checklist in their study design or in writing their papers (67 out of 68, 98.5%). Most of the papers (37 out of 68, 54%) did not mention anything about the potential risk of EF in their articles. In our assessment, we found that EF was important in 40 studies, but this issue was discussed in only nine of them (23%). We found that attention to the impact of LT as a source of error was important to 21% (14 out of 68) of the studies, while only five cases had discussed this error (Figure 1).

Discussion

In this review, we found that only one article (out of 68) used a standard checklist. Although EF was a potential threat in ecological studies, only close to a quarter of the studies highlighted this error. Among the studies where attention to LT was necessary, merely a third took the risk of this error into account.

Most of the ESs reviewed in this paper did not use a standard checklist to implement their studies. STROBE checklists were developed to standardize the protocols of observational studies. However, ESs did not have a specific guideline (2). Therefore, the need for a standard tool is evident to facilitate the systematic review of ESs (9). The checklist ensures the clarity and transparency of the research steps (10). It improves the quality and reliability and increases confidence in the study results (11). Our findings may help develop such a checklist as we showed EF and LT are important issues that need to be taken into account (10).

Although EF affected the results of many of the assessed studies, most authors did not adequately address this error. EF often causes a loss of details and generalizability (12). The relationship at the group level is probably not applicable to the individual level. Also, the relationship observed between groups may not necessarily hold within groups (13, 14). In individual studies, an observed

Table 1. The reviewed journals and their selected ecological articles.

Journals	Impact factor	Total article	Number (%) of selected articles based on their titles	Number (%) of selected ecological paper
Cancer Epidemiology	2.8	478	19 (4)	9 (1.9)
SSM-Population Health	4.1	753	10 (1.3)	8 (1.1)
Journal of Affective Disorder Reports	6.5	414	5 (1.2)	3 (0.7)
The lancet Regional Health-Western pacific	8.5	549	6 (1.1)	4 (0.7)
Health and Place	4.9	557	5 (0.9)	4 (0.7)
Environmental Research	8.8	4400	34 (0.8)	25 (0.6)
One Health	9	339	2 (0.6)	2 (0.6)
International Journal of Hygiene and Environmental Health	7.5	490	3 (0.6)	2 (0.4)
Journal of Infection and Public Health	7.5	978	5 (0.5)	3 (0.3)
Clinical Microbiology and Infection	13.3	1330	5 (0.4)	3 (0.2)
New Microbe and New Infect	3.8	406	1 (0.2)	1 (0.2)
Drug and Alcohol Dependence	4.8	1653	5 (0.3)	3 (0.2)
Annals of Medicine and Surgery	1.3	2624	2 (0.1)	1 (0.0)
Total	-	14971	102	68

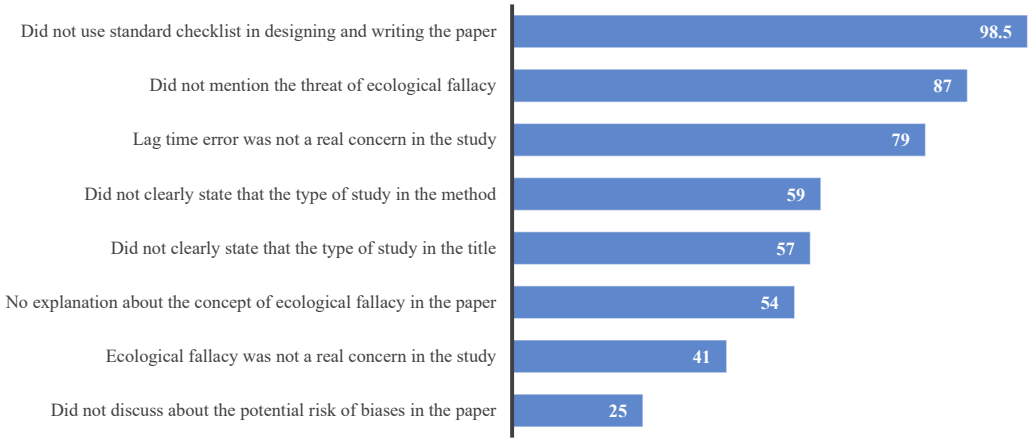

Figure 1. The results of the assessment of the ecological papers in top journals. The numbers are in percent

relationship at a level of one variable may not apply to the other levels of the same variable. For example, an observed relationship in the age group of 35 to 55 years may not hold for the age group of 20 to 35 years. When these data are aggregated in an ecological study, the pooled estimate may not present the magnitude and direction of associations (15).

The review of ESs showed that LT was neglected in most of these studies as well. It is vital that researchers consider LT in ESs as one of the primary methodological considerations. Depending on the study topic, an LT of even more than a decade may be reasonable, particularly in the context of non-communicable diseases. For example, if a lag time of 12 to 15 years is required to generate cancer following exposure to contaminated products, reducing the lag time to less than 10 years may show a false relationship in any type of study, including ESs (8). As another example, in a study aiming to assess the relationship between air pollution and COVID-19 infection, the three lag times of 7, 14, and 21 days between the level of air pollution and the daily incidence of infection may present completely different results. Because of the significant auto-correlations in both variables, short lag times will form a strong association, while long lag times may form reverse relationships. Therefore, researchers should consider the best LT based on the available evidence (16). This study had several strengths. A notable point was that it examined two major types of errors in ecological studies that need to be addressed to improve such research. Additionally, the data were carefully extracted by all of the authors, and reputable articles with a variety of impact factors were included.

Although we have not conducted a systematic search of ecological papers, the eligible articles extracted from the leading medical journals demonstrate the presence of these pitfalls. The current study can help improve ecological studies that investigate the causes or risk factors associated with a disease or mortality within a specific population. These studies typically identify correlations that inform hypothesis generation, making them a

valuable component of the research process. Therefore, it is recommended that authors consider such errors when designing ecological studies to enhance their results and contribute to the improvement of their research.

Conclusion

Our results showed that the quality of published ES papers, even in high-ranking journals, was concerning. Therefore, more attention to quality is necessary in designing and writing ESs. Although we selected only journals with the highest IFs that published only English papers, increasing the risk of publication bias, our findings may still apply to other journals and languages as the quality of published ESs was not acceptable even in these journals.

Despite the importance of ecological research, especially in understanding complex environmental and health-related issues, many studies failed to adequately address critical methodological factors such as the ecological fallacy and lag time. This lack of attention to methodological rigor limits the validity and generalizability of the results. Also, the results of this study suggest the necessity of the development and implementation of standardized guidelines and checklists to improve the quality of ecological research.

Authors' Contribution

Conceptualization and design: Naeemeh Shahdadi, AliAkbar Haghdoost.
Data curation: Naeemeh Shahdadi.
Formal analysis: Naeemeh Shahdadi.
Investigation: Naeemeh Shahdadi-Naser Nasiri, AliAkbar Haghdoost.
Methodology: Naeemeh Shahdadi, AliAkbar Haghdoost.
Project administration: AliAkbar Haghdoost.
Resources: Naeemeh Shahdadi, AliAkbar Haghdoost.
Software: Naeemeh Shahdadi, Naser Nasiri.
Supervision: AliAkbar Haghdoost.
Validation: Naeemeh Shahdadi -AliAkbar Haghdoost-Naser Nasiri.
Visualization: Naeemeh Shahdadi -AliAkbar Haghdoost-Naser Nasiri.
Writing–original draft: Naeemeh Shahdadi, Naser Nasiri.
Writing–review & editing: Naeemeh Shahdadi, AliAkbar Haghdoost.

Ethical Approval

Not applicable.

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