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Discussion of study limitations strengthens research through transparency

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In scientific research, it is not possible to prove a hypothesis as absolutely true. Because all studies are constrained by the time, resources, and expertise available to investigators, researchers must strike a balance between the effort invested and the strength of evidence required to reasonably support their hypothesis, making the acknowledgment of methodological limitations an essential component of responsible scientific reporting. Just as important as articulating the novelty and potential impact of a study is providing a transparent discussion of its limitations. While such limitations may restrict the scope of conclusions, they also highlight opportunities for future research and further development of the field.

Discussion of limitations can take several distinct forms:

•Theoretical limitations are related to the conceptual framework, assumptions, or scope of the research.

•Methodological limitations arise from the quality, quantity, or diversity of the data collected, the experimental setup, or the measurement tools used.

•Empirical limitations are challenges associated with the representativeness, validity, or reliability of the data, including sample size, sampling bias, or incomplete datasets.

•Analytical limitations pertain to restrictions on the accuracy, completeness, or significance of the findings.

•Ethical limitations occur when access to data, participant consent, privacy considerations, or regulatory requirements restrict the research.

Understanding the different types of limitations is important, but equally crucial is recognising why openly stating them strengthens scientific practice. Identifying and sharing the limitations of research has numerous benefits, and one of the most important is that it strengthens the overall argument by demonstrating the rigour of the scientific process. By acknowledging the boundaries of their study, authors show integrity and transparency, as well as a thoughtful understanding of their methodological choices. This ensures that the conclusions made in the study are evidence-based and appropriately contextualised.

Open discussion of limitations also benefits the broader community. By guiding readers to interpret findings only within the specific conditions under which they were generated, limitations discussion increases credibility of the study and support reproducibility. It allows others to build on the work responsibly and highlight opportunities for future investigation.

To uphold these principles, authors submitting to *Sensors & Diagnostics* are required to clearly outline the limitations of their study in the Discussion section, emphasising the need for further research and transparency in reporting. We also request that reviewers carefully assess the discussion of study limitations and report any significant limitations that may be missing, to ensure that the constraints of the research are clearly and meaningfully addressed.

Ultimately, editors will consider the limitations provided by authors and relevant reviewers comments when assessing whether a manuscript meets the journal's standards. The most important factor is the degree of transparency and thoughtfulness demonstrated in the study limitation discussion.

To assist authors in this process, we provide examples of common study limitations in sensors research, along with suggested phrasing, to help them write a clear and thoughtful limitations section.

1. Sample size and diversity

•Limited number of biological or environmental samples tested.

•Samples not representative of real-world variability.

Example phrasing:

"*The sensor was validated using a limited sample set, which may not fully capture the variability encountered in real-world applications.*"

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2. Controlled lab conditions *versus* real-world use

•Testing performed under highly controlled laboratory conditions.

•Sensor performance may differ in complex matrices.

Example phrasing:

"*Experiments were conducted in buffered solutions, which do not fully mimic the complexity of clinical samples.*"

3. Stability, durability, and reproducibility

•Long-term stability not tested.

•Limited repeatability due to sensor fabrication variability.

Example phrasing:

"*Long-term operational stability beyond 30 days was not examined.*"

4. Instrumentation constraints

•Dependence on benchtop equipment for detection or signal processing.

•Power consumption too high for portability.

Example phrasing:

"*The readout system currently requires external instrumentation, limiting point-of-care applications.*"

5. Selectivity and limit of detection (LOD)

•LOD sufficient for lab settings but not for regulatory thresholds.

•Selectivity insufficient in multi-analyte environments.

Example phrasing:

"*Although sensitive for single-analyte detection, competitive binding in multiplex setups was not evaluated.*"

6. Validation against standards

•Limited comparison with established diagnostic methods.

•Validation performed with spiked samples instead of clinical samples.

Example phrasing:

"*Sensor performance was benchmarked using spiked samples, which may not fully replicate clinical variability.*"

7. Data analysis limitations

•Machine learning models trained on small datasets.

•Risk of overfitting in pattern-recognition sensors.

Example phrasing:

"*The classification model may be over-fitted due to the limited dataset used for training.*"

The requirement to detail the limitations of the study in research articles published in *Sensors & Diagnostics* is a step towards greater accountability and transparency of research. Taking it together we aim to strengthen the journal, increase the reliability of the scientific record, and improve reproducibility across the field.

Prof. Xueji Zhang, Editor-in-Chief
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