Integrating Health Analytics tools to Enhance Pharmacological Management and Patient Outcomes in Hospital Settings

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Abstract

Background: The integration of Health Analytics tools such as business analytics (BA) and human resource (HR) analytics tools in healthcare has the potential to improve pharmacological management and patient outcomes. This study explores how these analytical tools can optimize drug administration processes, reduce medication errors, and enhance workforce efficiency in hospital settings. Methods: A mixed-methods approach was employed, combining case studies with empirical data analysis from hospital records, including medication administration logs, adverse drug event reports, staffing schedules, and patient health outcomes. Predictive modeling and machine learning techniques were utilized to identify patterns and correlations. Results: The application of BA facilitated the early detection of discrepancies in medication dispensing, leading to a 15% reduction in adverse drug events. HR analytics contributed to improved staff scheduling, decreasing nurse fatigue and associated medication errors by 20%. The synergistic use of BA and HR analytics resulted in enhanced patient recovery rates and optimized pharmacological interventions. Conclusion: The strategic implementation of business and HR analytics in hospital management can significantly improve pharmacological practices and patient health outcomes. This integrative approach supports the journal's emphasis on biomedical research and health interventions by demonstrating the practical applications of analytics in enhancing therapeutic efficacy and patient care.

Keywords: Business Analytics, Human Resource Analytics, Pharmacological Management, Patient Outcomes, Healthcare Analytics, Medication Safety.

Significance | This study demonstrates that integrated analytics optimize pharmacotherapy, improve clinical decisions, enhance workforce performance, and strengthen hospital-wide patient outcome strategies.

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1. Introduction

In the modern healthcare environment, firms must skilfully navigate the intricate interplay of clinical care, medication safety, financial efficiency, and technology advancement. Due to escalating healthcare costs, expanding patient demographics, and the increased incidence of chronic and inflammatory diseases, the necessity for data-driven methodologies to improve therapeutic efficacy has become critical (Ahmad et al., 2022; Marques et al., 2024). Hospitals encounter complex issues related to operational efficiency, accurate drug delivery, illness management, and workforce sustainability. The pressures are heightened in the management of high-risk treatments such as anti-angiogenic

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therapies or sepsis interventions here real-time decision-making, pharmacovigilance, and interdisciplinary coordination are crucial for optimizing outcomes (Crowther & Warkentin, 2008; Singh & Chandra, n.d.; Wang et al., 2024).

In this intricate landscape, business analytics (BA) has arisen as a revolutionary influence in healthcare systems. Historically concentrated on optimizing hospital operations and financial strategies, BA now assumes a crucial role in enhancing clinical effectiveness, ensuring pharmaceutical safety, and facilitating biological monitoring. It facilitates predictive modelling, fraud detection, and the optimization of patient care processes by utilizing structured and unstructured data from electronic health records, prescription systems, and adverse medication event reports (Beam & Kohane, 2018; Rehman et al., 2022). Institutions like Mount Sinai and Cleveland Clinic have illustrated how analytics may enable early sepsis alerts, forecast readmissions, and promote the judicious application of therapeutic measures ensuring that pharmacological treatment is both secure and prompt (Pelluru, 2020; Ifty et al., 2024).

However, data obtained exclusively from operations and finance is inadequate for addressing contemporary health concerns. The incorporation of Human Resource (HR) analytics is essential for synchronizing labour allocation with clinical requirements. HR analytics utilizes real-time insights to predict staffing requirements, minimize medication errors associated with fatigue, and allocate specialized teams for disease-specific interventions, especially in environments where biomarkers indicate developing inflammatory or angiogenic responses (Patil & Shankar, 2023; Rao et al., 2025). When associated with clinical indicators such as C-reactive protein (CRP), procalcitonin, or VEGF expression HR analytics enables proactive decision-making that directly improves pharmaceutical therapies (Singh & Chandra, n.d.; Crowther & Warkentin, 2008; Wang et al., 2024).

Evaluate the use of VEGF inhibitors like bevacizumab, which are associated with undesirable effects such as hypertension, bleeding, and thrombosis. Predictive HR analytics can allocate oncology personnel skilled in addressing these consequences dynamically, according to treatment protocols and risk classification models (Lopes-Coelho et al., 2021; Sánchez-Herrero et al., 2024). In cancer centers that adopted these approaches, analytics-driven staffing resulted in a quantifiable 15% reduction in VEGF-related hypertensive incidents. In the management of diabetic foot ulcers (DFU), the incorporation of CRP-triggered staffing modifications led to an 18% reduction in sepsis-related sequelae, demonstrating the tangible therapeutic benefit of HR-informed pharmaceutical protocols (Wang et al., 2024; Rao et al., 2025).

These advancements indicate a transition towards biomedical analytics, wherein BA and HR systems collaborate with individualized biological data of patients. Predictive models integrating heart rate variability, oxygen saturation, or renal function are now associated with treatment adherence and medication administration schedules, facilitating real-time adjustments and personalized therapy (Ahmad et al., 2022; Ibeh et al., 2024). At the Cleveland Clinic, integrative analytics frameworks have been employed to identify medication-related adverse events (ADEs) prior to symptom manifestation, resulting in a 15% decrease in ADEs and enhanced recovery rates (Pelluru, 2020). This collaboration between operational intelligence and biological markers illustrates the journal's focus on translational health research and targeted solutions.

A major domain of convergence is the design of health interventions driven by analytics. Predictive scheduling models and wearable monitoring aid health systems in providing early treatments for chronic illness management, decreasing readmission rates, and averting negative pharmaceutical effects (Rehman et al., 2022; Damian et al., 2025). Kaiser Permanente's implementation of predictive appointment scheduling enhanced medication adherence among chronic illness patients by 25%, whereas Mayo Clinic's incorporation of remote monitoring and EHR analytics reduced heart failure readmissions by 15% (Ahmad et al., 2022). These results illustrate how advanced analytics can directly impact drug efficacy, patient adherence, and treatment continuity, thereby addressing pharmacological and biological priorities.

Moreover, HR analytics plays a crucial role in pharmacovigilance and health equality by detecting fraud, staffing discrepancies, and compliance vulnerabilities. Hospitals are utilizing AI-driven HR systems to identify "ghost" personnel, uncover false payroll claims, and verify credential authenticity, thus ensuring institutional integrity and patient safety (Chowdhury et al., 2022; Valli, 2024). These methods guarantee that licensed and specialized individuals are assigned to high-risk pharmaceutical interventions, thereby improving the accuracy and accountability of therapy administration. In angiogenesis-centered care, interactive HR dashboards now dynamically respond to biomarker alarms, facilitating the prompt allocation of staff for side-effect management and monitoring (Singh & Chandra, n.d.; Rao et al., 2025).

Innovations like explainable AI (XAI), blockchain, and federated learning are enhancing the possibilities for secure and transparent analytics in pharmaceutical treatment. These solutions enhance clinician confidence in AI-generated predictions, facilitate collaborative research while maintaining patient anonymity, and bolster data integrity across institutions (Adeniran et al., 2024; Omidian, 2024; Hassan et al., 2022). Hospitals employing blockchain-based monitoring have successfully mitigated fraudulent transactions and safeguarded medicine distribution records, so ensuring that analytics-driven pharmacology is both ethically sound and legally compliant.

To address these multifaceted requirements, hospitals are progressively establishing hybrid analytic infrastructures that integrate business, human resources, and biomedical analytics to monitor patient biomarkers, workforce allocation, therapy schedules, and recovery indicators in real time. The result is a responsive, integrated care paradigm that enhances pharmaceutical interventions while minimizing systemic inefficiencies and resource wastage (Nianga, 2024; Ibeh et al., 2024). Empirical evidence substantiates this transformation: hospitals that implemented integrated analytics platforms observed quantifiable enhancements in patient safety, drug efficacy, staff coordination, and cost-effectiveness (Callahan & Shah, 2017; Malik et al., 2023; Sunny et al., 2023).

This study intends to provide a thorough investigation of how business and HR analytics collaboratively improve pharmaceutical management and patient health outcomes in hospital environments. The research elucidates how analytics tools can directly facilitate treatment planning, drug safety, and biomarker-guided interventions by analyzing case studies, institutional data, and predictive modeling approaches, in accordance with the journal's emphasis on angiogenesis, inflammation, and integrative therapeutic practices. This paper highlights the clinical significance of data-driven human resource management in aligning personnel skills with biologically based treatment needs, providing a framework that facilitates personalized care, immediate clinical decision-making, and institutional sustainability in intricate hospital settings.

2. Research Methodology

2.1 Study Design and Scope

This study used a mixed-methods approach, integrating empirical data analysis with qualitative case studies to investigate the amalgamation of business and HR analytics in improving pharmaceutical management and patient outcomes. The aim is to assess the impact of predictive and real-time analytics tools on hospital processes, medicine administration, biomarker monitoring, and personnel allocation, in order to enhance therapeutic interventions and health outcomes. The research focuses on hospitals functioning under intricate clinical and logistical limitations, including those addressing disorders linked to angiogenesis, chronic inflammation, and medication hazards (Crowther & Warkentin, 2008; Singh & Chandra, n.d.; Wang et al., 2024).

2.2 Data Collection and Sources

Data were gathered from three primary sources to guarantee a thorough examination of the impact of analytics tools on clinical and pharmacological functions. Initially, administrative data from hospital business analytics systems were utilized, including patient admittance records, treatment durations, discharge summaries, and billing information. Secondly, clinical and pharmaceutical systems supplied biomedical data, including medication administration records, adverse drug event (ADE) reports, and electronic health records (EHRs) featuring pertinent biomarkers such as CRP, VEGF, and procalcitonin levels. Third, human resource systems were utilized to analyze data concerning staff schedules, absenteeism trends, certification verifications, and performance assessments. Quantitative data were collected through standardized surveys distributed to hospital administrators, clinical pharmacists, nurse managers, and IT workers. These surveys were designed to evaluate impressions of analytics-based decision-making, precision in treatment execution, and quantifiable enhancements in patient recovery results. A pilot study was undertaken to ensure the internal reliability of the survey instrument, utilizing Cronbach's alpha to validate consistency. Qualitative data were gathered via semi-structured interviews with department directors, pharmacovigilance officers, and biomedical data analysts. This methodology facilitated the triangulation of insights and permitted the incorporation of contextual comprehension from hospitals utilizing predictive analytics platforms to oversee pharmacological side effects, especially in contexts related to anti-angiogenic therapy and inflammatory disease management (Ahmad et al., 2022; Pelluru, 2020; Sánchez-Herrero et al., 2024).

2.3 Analytical Framework and Biomedical Metrics

The investigation was informed by a theoretical framework based on systems theory and decision theory, which are particularly relevant to contemporary healthcare ecosystems. Decision theory highlights the importance of data-driven and predictive instruments in overseeing drug safety, strategizing workforce needs, and averting unfavorable medical occurrences (Rao et al., 2025). Systems theory was employed to envision hospitals as adaptive entities where pharmacological workflows, clinical personnel, and biomarker surveillance systems must function in an integrated and synchronized manner (Sunny et al., 2021; Rehman et al., 2022). Quantitative data were analyzed through descriptive statistics, regression models, and correlation analysis to assess the impact of analytics tools on pharmacological outcomes, including the reduction of adverse drug events (ADEs), normalization of biomarkers such as CRP and VEGF post-therapeutic interventions, and readmission rates for inflammation-related conditions like diabetic foot ulcers. Simultaneously, qualitative data obtained from interviews were examined using inductive content analysis, adhering to the Braun and Clarke methodology. Thematic coding was utilized to identify essential categories, such as real-time analytics for drug risk assessment, HR responsiveness to biomarker-triggered notifications, and enhancements in evidence-based decision-making about therapeutic planning. These analytical procedures facilitated a thorough comprehension of how

integrative analytics frameworks influence pharmaceutical safety and enhance clinical operations.

2.4 Ethical Considerations

Given the utilization of sensitive biomedical data and personally identifiable clinical information, stringent ethical concerns were adhered to during all phases of the investigation. All electronic health records (EHRs) and administrative data were anonymized before analysis and stored in encrypted digital environments, accessible just to authorized people. The research adhered to globally acknowledged data protection standards, including the General Data Protection Regulation (GDPR) and the Health Insurance Portability and Accountability Act (HIPAA), thus safeguarding patient confidentiality and institutional security (Ifty et al., 2024; Hassan et al., 2022). Informed consent was acquired from all participants engaged in the survey, interviews, and case studies. The permission agreements explicitly delineated the study's objectives, data collection procedures, the voluntary aspect of participation, and the participants' entitlement to withdraw at any moment without repercussions. To alleviate any algorithmic bias in the assessed analytics systems especially those employed in ADE prediction and risk-based personnel allocation machine learning models underwent validation through cross-validation methodologies. Fairness evaluations were performed to guarantee that model projections did not disproportionately impact individuals based on factors such as age, gender, comorbidity status, or staff role classifications (Edison, 2023; Omidian, 2024). These ethical protections enhanced the transparency, accountability, and integrity of the research.

2.5 Summary of Literature Selection (PRISMA Framework)

A PRISMA-guided literature evaluation was done to reinforce the study's conceptual framework and ensure its compatibility with established research. The review entailed a systematic search of four principal academic databases PubMed, Scopus, Web of Science, and Google Scholar concentrating on scholarly publications published from January 2018 to April 2024. The principal search terms encompassed business analytics, HR analytics, pharmaceutical safety, biomarker-guided therapy, inflammatory disorders, and angiogenesis. Only peer-reviewed articles, systematic reviews, and empirical research from Q1 and Q2 journals published in English with full-text access were deemed eligible for inclusion. Studies were chosen if they focused on the utilization of analytics in healthcare environments, namely with pharmaceutical management, human resource optimization in clinical processes, or analytics-driven health interventions. Exclusion criteria were implemented for editorials, opinion articles, non-peer-reviewed papers, blog postings, and research lacking significant clinical or therapeutic value. Further restrictions were implemented for articles not pertinent to hospital-based healthcare delivery, including those concentrating solely on veterinary science, dental practice, or general HR frameworks outside the biological setting. Following the evaluation of titles and abstracts, and the elimination of duplicates, 72 full-text papers were selected to inform the design and interpretation of this study's framework and results. The systematic inclusion approach guarantees that the analytical, biological, and pharmacological aspects of our investigation are grounded in high-quality, evidence-based literature (Malik et al., 2023; Sunny et al., 2023; Rao et al., 2025).

3. Results and Discussions

3.1 Analytics-Based Improvements to Pharmacological Management

The use of analytics tools within hospital systems has markedly enhanced the quality and safety of pharmaceutical care. Of the three analytics domains business, HR, and biomedical biomedical analytics has shown to be the most revolutionary in clinical decision-making and therapeutic accuracy. Data indicates that 92% of participating institutions recognized that real-time monitoring of pharmacological interventions through biomedical dashboards enhanced dosage precision and treatment safety. The utilization of biomarkers like C-reactive protein (CRP) and vascular endothelial growth factor (VEGF) enabled the early identification of inflammatory and angiogenic disease mechanisms. This facilitated swift modifications in pharmacotherapy for conditions including rheumatoid arthritis, sepsis, and cancer-associated angiogenesis. Business analytics was crucial, especially in enhancing pharmaceutical logistics and minimizing treatment delays. Hospitals utilizing analytics to optimize pharmaceutical supply chains have shown a decrease in emergency stock-outs and enhanced responsiveness to prescribing patterns. These tools enabled pharmacy managers to predict peak demand periods and modify procurement plans accordingly. Simultaneously, HR analytics offered crucial assistance in high-risk pharmacotherapy environments by allocating personnel according to qualifications, experience, and immediate fatigue notifications. This congruence between job difficulty and human capability diminished medication errors and facilitated more uniform pharmacological treatment.

3.2 Biomarker-Guided Treatment Optimization

Biomarker-guided medication has rapidly emerged as a fundamental principle of precision medicine, and our study underscores its clinical efficacy. Real-time analytics systems monitoring biomarkers such as CRP, VEGF, and procalcitonin have been shown to improve clinicians' capacity to dynamically adjust treatment regimens. In hospitals equipped with modern biomedical analytics technologies, 90% of doctors observed substantial enhancements in patient-specific treatment planning. In instances of inflammatory bowel disease and diabetic ulcers,

Table 1. PRISMA-Based Literature Selection Criteria

Criteria	Inclusion	Exclusion
Type of Publication	Peer-reviewed articles, systematic reviews	Editorials, blog posts, non-peer-reviewed sources
Language	English only	Non-English publications
Scope	Studies focusing on healthcare analytics, pharmacology, HR in clinical care	Articles lacking clinical, therapeutic, or pharmacological relevance
Population	Hospital-based studies, health systems research, pharmacological interventions	Veterinary, dental-only, or non-clinical HR management studies
Accessibility	Full-text availability	Abstract-only articles or inaccessible paywalled content

Table 2. Comparative Impact of Analytics Types on Pharmacological Management and Patient Outcomes

Analytics Type	Pharmacological Management (%)	Patient Outcomes (%)	Readmission Reduction (%)	Support for Real-Time Alerts (%)
Business Analytics	85	80	75	78
HR Analytics	70	65	60	67
Biomedical Analytics	92	90	88	95

Table 3. Use-Case-Based Efficiency and Safety Gains by Analytics Type

Analytics Type	Top Use-Case	Efficiency Improvement (%)	Adverse Event Reduction (%)
Biomedical Analytics	Biomarker-Guided Medication Adjustment	93%	89%
Business Analytics	Pharmacy Stock Optimization	87%	75%
HR Analytics	Fatigue Risk Alerts & Competency Scheduling	72%	66%

biomarker trends were utilized to adjust immunomodulatory medications, thereby limiting flare-ups and decreasing hospitalization requirements.

The implementation of these technologies facilitated a transition from reactive to proactive pharmaceutical approaches. Through the constant monitoring of molecular signals, clinicians could predict adverse outcomes, prevent drug interactions, and reduce the therapeutic delay between diagnosis and intervention. This resulted in a quantifiable enhancement in patient recovery rates and a decrease in healthcare utilization.

3.3 Human Resources Analytics and Pharmacotherapy Workforce Optimization

Although sometimes undervalued, HR analytics has demonstrated its essential role in facilitating safe and effective pharmaceutical administration. Organizations utilizing sophisticated workforce analytics experienced a 67% enhancement in scheduling efficiency and a 60% decrease in clinical staffing discrepancies. The implementation of machine learning-based tiredness alert systems enabled HR departments to recognize burnout concerns and modify schedules accordingly. Furthermore, competency-based allocation guaranteed that clinicians and nurses with the most pertinent experience were designated to manage intricate drug regimens, like chemotherapy or biologic infusions. The interview findings validated these quantitative tendencies. Pharmacists and clinical supervisors emphasized that HR analytics diminished the incidence of staff-related errors, improved team communication, and cultivated a safer medication environment. In emergency rooms and intensive care units (ICUs), real-time analytics enhanced the safety of shift transitions and reduced medication delivery errors.

3.4 Business Analytics in Pharmaceutical Logistics and Risk Assessment

Business analytics systems, mostly centered on operational performance, exhibited significant influence in overseeing the drug supply chain and its related hazards. Hospitals utilizing data-driven procurement systems attained an 85% efficiency rate in pharmaceutical inventory management. These technologies reduced duplicate orders, enhanced expiration monitoring, and automated notifications for replenishing critical medications. This was especially significant in relation to chronic conditions necessitating prolonged pharmacological treatment, such as diabetes, hypertension, and autoimmune disorders. Furthermore, the integration of analytics with electronic health records (EHRs) has permitted hospitals to correlate patient-specific prescribing data with pharmacy inventory levels. This enabled the forecasting of demand increases and enhanced preparedness for therapeutic interventions. The effect was seen in both patient outcomes and institutional cost reductions, particularly in minimizing last-minute pharmaceutical procurement or emergency outsourcing.

3.5 Comparative Analysis of Analytics Modalities

An analysis of the three analytics areas underscores their distinct yet synergistic functions in enhancing pharmaceutical management and patient outcomes. Table 2 delineates the efficacy of each analytics type across four effect categories: pharmaceutical control, patient outcomes, readmission reduction, and real-time alert support.

Table 2 demonstrates that biomedical analytics surpassed other disciplines in almost every category. It provided the most significant enhancements in pharmaceutical precision (92%) and clinical outcomes (90%), succeeded by readmission prevention (88%). HR analytics significantly enhanced staff safety and real-time alert systems, whilst business analytics established a robust foundation for logistical readiness and drug accessibility.

3.6 Use-Case Efficiency Gains Across Domains

In addition to aggregated impact scores, particular use cases offer a more profound understanding of the functional value of each type of analytics. Table 3 delineates the primary use cases categorized by analytics, accompanied by corresponding enhancements in efficiency and safety outcomes.

Biomarker-guided dosage modifications enhanced the efficiency of care provision and markedly diminished the incidence of adverse drug events. Pharmacy inventory optimization with business analytics alleviated medicine shortages and guaranteed prompt treatment. Simultaneously, HR analytics facilitated safer drug administration via proactive staffing strategies.

3.7 Synergistic Analytical Ecosystems and Therapeutic Outcomes

The most significant findings originated from hospitals that incorporated all three analytics areas into a unified decision-support system. A tertiary hospital's use of a consolidated dashboard decreased pharmaceutical issues in its ICU by 20% during a six-month timeframe. This result was attained by the synchronization of ADE warnings, automatic medication reminders, tiredness tracking, and EHR-integrated inventory systems. Stakeholders indicated that inter-departmental collaboration significantly enhanced, with pharmacists, nurses, and clinicians synchronized via centralized analytics access. These synergistic models indicate the future of pharmaceutical management characterized by being data-driven, collaborative, adaptive, and ethically regulated.

3.8 Perspectives of Stakeholders and Thematic Insights

Qualitative interviews with healthcare experts identified consistent themes corresponding with the quantitative study. Terms such as "precision dosing utilizing molecular markers," "workflow enhancement through fatigue forecasting," and "inventory preparedness via real-time dashboards" were commonly encountered. Clinicians emphasized the importance of prompt alerts in preventing therapeutic errors, whereas administrators noted improved resource forecasting and accountability. Pharmacovigilance officers saw improved adherence to treatment guidelines and a diminished reporting load.

4. Conclusion and Prospective

This study emphasizes the revolutionary potential of combining commercial, human resource (HR), and biomedical analytics in hospital settings to optimize pharmaceutical management and boost patient outcomes. By integrating operational, clinical, and personnel-related data systems, healthcare facilities can shift from reactive to proactive models of care that are more individualized, efficient, and secure. Of the three categories examined, biomedical analytics demonstrated the most direct influence on pharmacological precision and therapeutic safety. The real-time monitoring of biomarkers like C-reactive protein (CRP) and vascular endothelial growth factor (VEGF) facilitated adaptive medication modifications, especially in the management of inflammatory and angiogenic disorders. These approaches markedly diminished adverse drug events (ADEs), expedited recovery periods, and enhanced drug consumption, highlighting the importance of genetic data in customizing pharmacotherapy. Business analytics, historically linked to administrative efficiency, has shown significant impact in domains such as pharmaceutical supply chain optimization, medicine availability predictions, and cost containment. Hospitals implementing data-driven inventory systems had reduced medicine shortages and improved synchronization between prescribing trends and stock levels, hence enhancing continuity of treatment. HR analytics has become an essential facilitator of safe medication practices by guaranteeing the

appropriate individuals are allocated to the correct clinical activities at the optimal moment. The implementation of tiredness risk monitoring, credential-matching algorithms, and adaptive scheduling technologies improved staff performance and decreased error rates, especially in high-risk pharmaceutical environments like oncology and critical care. However, the amalgamation of business, HR, and biomedical analytics offers a persuasive avenue for improving pharmaceutical management and promoting patient-centred treatment. Future research ought to investigate longitudinal outcomes, the alignment of cross-departmental analytics, and the function of AI-driven decision support systems in maintaining these enhancements. Health systems that adopt analytics enhance operational efficiency while establishing a basis for safer, more effective, and more responsible pharmaceutical therapies.

Author contributions

MRA, MA, and MEC were responsible for conceptualization, fieldwork, data analysis, original draft writing, editing, funding acquisition, and review. SRCU, KR, BAS, and MSU contributed to research design, methodology validation, data analysis, visualization, and were involved in reviewing and editing the manuscript. RC and SH contributed to conceptualization, investigation, visualization, reviewing, editing, and proofreading. SAS was involved in conceptualization, methodology validation, data analysis, investigation, reviewing, funding acquisition, supervision, and editing. All authors have read and approved the final version of the manuscript.

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Competing financial interests

The authors have no conflict of interest.

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