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RESEARCH ARTICLE

Technical Efficiency Analysis of Stunting Intervention Programs in Central Java Province: A Two-Stage Data Envelopment Analysis (DEA) Approach

Anggie Neva Deliza[1*], Nenik Woyanti[2]
[1]Program Studi Ekonomi, Fakultas Ekonomi dan Bisnis, Universitas Diponegoro, Indonesia

ABSTRACT
Stunting remains a major challenge to human development in Indonesia, as it directly affects the quality of human resources and long-term economic productivity. Central Java Province is among the national priority areas for stunting reduction; however, the efficiency of its intervention programs remains suboptimal. This study aims to analyze the technical efficiency of stunting intervention programs in Central Java Province during the 2019–2023 period by applying a Two-Stage Data Envelopment Analysis (DEA) approach. The study employs secondary data obtained from the Central Statistics Agency (BPS), the Central Java Provincial Health Office, and the Directorate General of Fiscal Balance of the Ministry of Finance of the Republic of Indonesia. Input variables include the percentage of infants receiving exclusive breastfeeding, the percentage of infants with complete basic immunization, the percentage of deliveries in health facilities, and the percentage of households with access to safe drinking water and proper sanitation. The output variable is represented by the percentage of children under five with normal nutritional status (height-for-age). The findings reveal that only 5.71 percent of districts or municipalities in Central Java achieved perfect technical efficiency, namely Banjarnegara and Grobogan Regencies. This indicates that most regions have not yet optimized their resources and health service capacities to achieve effective stunting interventions. The study highlights the need for strengthened intersectoral coordination, improvement of basic health service facilities, and better allocation of nutrition-related budgets to enhance systemic efficiency in reducing stunting prevalence at the regional level.

KEYWORDS:
Technical Efficiency; Stunting Intervention; Data Envelopment Analysis; Nutrition; Central Java

INTRODUCTION

Stunting, characterized by impaired linear growth in children due to chronic malnutrition, remains a persistent global public health concern. According to the World Health Organization (WHO, 2023), stunting affects more than 148 million children under five worldwide, predominantly in low- and middle-income countries. Stunted growth during the first 1,000 days of life leads to irreversible consequences, including cognitive impairment, lower educational attainment, and decreased economic productivity in adulthood (de Onis & Branca, 2016). For developing countries such as Indonesia, reducing stunting is a key determinant for achieving Sustainable Development Goal (SDG) 2, which targets the elimination of all forms of malnutrition by 2030.

Despite significant policy attention, Indonesia continues to face slow progress in stunting reduction. The National Nutrition Status Survey reported that the national prevalence of stunting among children under five reached 21.5 percent in 2023, only a minor decline from 21.6 percent in 2022 (Ministry of Health, 2024). This stagnation reflects structural challenges in program coordination, resource allocation, and community participation. Previous research indicates that the effectiveness of stunting interventions depends not only on the quantity of health services provided but also on the efficiency with which resources are utilized (Nursyamsiyah et al., 2021; Komalasari et al., 2020). Therefore,

CONTACT Anggie Neva Deliza anggienevadeliza@gmail.com

evaluating the technical efficiency of intervention systems becomes crucial to ensure that limited resources generate optimal outcomes in improving child nutritional status.

Central Java Province represents a critical case for this evaluation. As one of Indonesia's most populous regions, Central Java has consistently been designated a priority area for stunting prevention by the National Team for the Acceleration of Poverty Reduction (TNP2K) and the Vice President's Secretariat (2023). Although the prevalence of stunting in Central Java has gradually decreased—from 27.7 percent in 2019 to 20.7 percent in 2023—it remains above the WHO threshold of 20 percent (Coordinating Ministry for Human Development and Cultural Affairs, 2023). This suggests that regional programs have yet to achieve their full technical potential in translating government investment into improved nutritional outcomes.

The efficiency of public health programs, particularly those addressing complex multi-sectoral issues like stunting, can be rigorously assessed through the Data Envelopment Analysis (DEA) framework. DEA is a non-parametric method that evaluates the relative efficiency of decision-making units (DMUs) by comparing multiple inputs and outputs through linear programming (Charnes, Cooper, & Rhodes, 1978; Banker, Charnes, & Cooper, 1984). In the context of health systems, DEA enables policymakers to identify which regions or institutions perform best in converting health investments into outcomes, and which require performance improvement (Liang et al., 2008; Hollingsworth, 2008). Applying a two-stage DEA model allows for a more refined understanding of both cost and system efficiency in the stunting intervention process.

Empirical studies on stunting efficiency in Indonesia remain limited. Previous research has primarily focused on descriptive analyses of prevalence or program implementation (Hatijar, 2023; Dinas Kesehatan Provinsi Papua, 2024), with few employing robust quantitative efficiency models. The work of Nadya and Atmanti (2022) and Rapiuddin and Rusydi (2017) demonstrate the usefulness of DEA in assessing resource utilization efficiency, yet regional-level applications on stunting interventions are scarce. Therefore, this study seeks to fill the empirical gap by evaluating the technical efficiency of stunting intervention systems across districts and municipalities in Central Java Province using a Two-Stage DEA approach.

The findings of this research contribute to both academic and policy discussions. Academically, it extends the application of efficiency theory within the health economics domain by integrating multi-dimensional indicators of stunting interventions. From a policy perspective, it offers evidence-based insights for local governments to optimize budget allocation, improve health service delivery, and enhance the overall performance of stunting reduction programs

LITERATURE REVIEW

Efficiency theory plays a central role in economics and public management as it provides a quantitative basis for evaluating how effectively inputs are converted into outputs. Within this framework, efficiency is defined as the ratio of output produced to input utilized, reflecting how well resources are transformed into desirable outcomes without waste (Farrell, 1957). In the context of public health, efficiency assessment helps policymakers understand whether program investments yield proportional improvements in population health indicators. Technical efficiency, in particular, measures how close a decision-making unit (DMU) operates to the best practice frontier, given available technology and resources (Hollingsworth, 2008). A technically efficient unit produces the maximum attainable output from a given set of inputs, or conversely, uses the minimum inputs required to achieve a certain level of output (Rapiuddin & Rusydi, 2017). This concept is crucial in public sector analysis, where budget constraints demand the optimal use of limited resources to maximize social welfare outcomes.

The measurement of efficiency in health systems has evolved with the development of non-parametric frontier methods, most notably Data Envelopment Analysis (DEA). Originally introduced by Charnes, Cooper, and Rhodes (1978), DEA provides a mathematical approach to assess the relative efficiency of comparable units—such as hospitals, health centers, or local governments—by constructing an empirical efficiency frontier. The model operates under the assumption that each unit converts multiple inputs (resources, staff, funds) into multiple outputs (health outcomes, service coverage). Banker, Charnes, and Cooper (1984) extended the model by introducing the Variable Returns to Scale (VRS) assumption, allowing for heterogeneity in production scales across units. DEA's advantage lies in its ability to evaluate efficiency without requiring explicit functional forms between inputs and outputs, which is particularly valuable for public health programs characterized by complex, multi-sectoral interactions (Zhu, 2020).

The two-stage DEA model represents a methodological advancement that decomposes the efficiency process into interconnected sub-processes, thereby capturing both cost efficiency and system efficiency. Liang, Cook, and Zhu (2008) conceptualized the two-stage framework to address the internal structure of production systems, where outputs from the first stage act as intermediate inputs for the second stage. In public health studies, this approach is especially relevant because intervention programs often consist of sequential stages—such as resource allocation, service delivery, and outcome generation. For instance, the first stage may assess the efficiency of government spending on nutrition and sanitation programs, while the second stage evaluates how those services translate into improved child nutritional status. Recent studies have demonstrated that this approach provides a more comprehensive understanding of performance heterogeneity among local governments or health institutions (Tone & Tsutsui, 2019; Basso et al., 2022).

In Indonesia, research applying DEA to evaluate stunting interventions remains limited. Nadya and Atmanti (2022) utilized a single-stage DEA to assess efficiency in national stunting programs and identified regional disparities in performance. However, the use of the two-stage model remains underexplored, particularly at the provincial level. This study addresses that gap by employing a two-stage DEA approach to analyze technical efficiency across districts and municipalities in Central Java. The method allows for disentangling the efficiency of resource utilization in intermediate indicators—such as exclusive breastfeeding rates, immunization coverage, and access to sanitation—from the overall efficiency in achieving improved child nutritional outcomes.

The relevance of DEA to stunting intervention lies in its ability to integrate multi-dimensional data within a single analytical framework. Stunting prevention involves both *nutrition-specific* interventions (e.g., breastfeeding promotion, immunization, maternal care) and *nutrition-sensitive* interventions (e.g., clean water access, sanitation, poverty reduction). These components interact dynamically across sectors, making traditional univariate analyses insufficient to capture program efficiency (Bhutta et al., 2020). DEA provides an empirical means to evaluate whether a region is performing efficiently relative to its peers and to identify potential benchmarks for policy improvement. When applied to stunting reduction, DEA can highlight which local governments achieve high outcomes with relatively fewer resources and which lag despite similar investment levels.

From a theoretical standpoint, this research draws upon the efficiency frontier framework and systems theory in public administration. The efficiency frontier represents the set of best-performing units that serve as references for less efficient counterparts. Systems theory, as applied to public health governance, views stunting intervention as an integrated system of interrelated components—inputs (resources, facilities), processes (program implementation), and outputs (improved nutrition status). The two-stage DEA approach aligns with this perspective by decomposing the system into interdependent stages that mirror the policy implementation chain. This theoretical integration

underscores the importance of both vertical coordination (across government levels) and horizontal coordination (across sectors) in improving systemic efficiency.

Recent global and regional studies reinforce the necessity of efficiency analysis for achieving sustainable health outcomes. For example, Tandon et al. (2022) demonstrated that improving health system efficiency can yield outcomes comparable to a 10–20 percent increase in public health expenditure in low- and middle-income countries. Similarly, Asante et al. (2023) emphasized that efficiency-based performance evaluation is critical for optimizing resource allocation under fiscal constraints. These findings validate the analytical relevance of DEA as a policy instrument for identifying inefficiencies and designing targeted interventions. By applying this theoretical and empirical framework, the present study contributes to advancing evidence-based decision-making for stunting reduction in Indonesia, highlighting how technical efficiency can serve as a cornerstone for equitable and sustainable public health improvement.

METHODOLOGY

This study employs a quantitative approach using the Two-Stage Data Envelopment Analysis (DEA) method to evaluate the technical efficiency of stunting intervention programs across 35 districts and municipalities in Central Java Province for the period 2019–2023. DEA is a non-parametric technique based on linear programming that measures the relative efficiency of decision-making units (DMUs) with multiple inputs and outputs. The method is particularly suitable for assessing public sector performance, as it does not require a predefined functional relationship between input and output variables and accommodates heterogeneous decision units operating under different scales of production (Charnes et al., 1978; Banker et al., 1984). The two-stage DEA model used in this study follows the conceptual structure proposed by Liang, Cook, and Zhu (2008), which divides the production process into two interrelated stages to capture a more comprehensive understanding of systemic efficiency.

The first stage represents the cost or input efficiency, which evaluates how effectively each district allocates and utilizes resources related to stunting interventions. The second stage measures the system efficiency, assessing how intermediate outputs from the first stage contribute to final health outcomes. This sequential structure reflects the real-world process of public health interventions, where financial and programmatic inputs are first transformed into service coverage, and subsequently into health impacts. By decomposing the efficiency process, the two-stage model provides insights into both operational and systemic weaknesses within local government programs.

The DEA model in this study adopts an input-oriented approach under the Variable Returns to Scale (VRS) assumption. The input orientation is chosen because local governments have greater control over resource allocation than over final outcomes, making it more appropriate to minimize input use for a given level of output. The VRS assumption is employed to accommodate scale heterogeneity among districts, recognizing that larger or more urbanized regions may experience different efficiencies compared to smaller or rural areas. The efficiency score for each DMU ranges from 0 to 1, where a score of 1 indicates full efficiency (the DMU lies on the efficient frontier), and scores below 1 signify inefficiency relative to peer units.

Mathematically, the DEA efficiency model is expressed as follows:

$$\text{Maximize } h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}$$

subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, j = 1,2,\ldots,n$$
$$u_r, v_i \geq 0$$

where $h_k$is the efficiency score of the k^{th}decision-making unit, $y_{rj}$and x_{ij}represent the outputs and inputs respectively, and $u_r$and $v_i$are the corresponding weights assigned to outputs and inputs. The model seeks to determine the optimal set of weights that maximizes the efficiency score of each DMU while ensuring that no DMU's weighted ratio exceeds unity. This linear programming problem is solved using the DEAP version 2.1 software developed by the University of Queensland.

The variables employed in the analysis are derived from publicly available secondary data sources, including the Central Statistics Agency (BPS), the Central Java Provincial Health Office, and the Directorate General of Fiscal Balance, Ministry of Finance of the Republic of Indonesia. The selection of input and output variables aligns with the national stunting intervention framework established by the Vice President's Secretariat (Setwapres, 2017), which emphasizes both nutrition-specific and nutrition-sensitive interventions. The input variables include: (1) the percentage of infants receiving exclusive breastfeeding, (2) the percentage of infants receiving complete basic immunization, (3) the percentage of women aged 15–49 years who gave birth in a health facility within the past two years, (4) the percentage of households with access to safe drinking water, and (5) the percentage of households with access to adequate sanitation. These indicators capture the key components of government interventions that directly or indirectly affect child nutritional outcomes. The output variable represents the percentage of children under five with normal height-for-age (H/A) status, which reflects the success of intervention programs in improving nutritional well-being.

Data were processed and analyzed for each year from 2019 to 2023, allowing the estimation of annual efficiency scores and temporal comparisons across districts and municipalities. The resulting efficiency scores were further analyzed to identify regional disparities and potential determinants of inefficiency. The interpretation of DEA results focuses on identifying "best practice" units—those that operate on the efficient frontier—and comparing less efficient regions against these benchmarks. Additionally, slack analysis was conducted to measure the extent of input excesses and output shortfalls, thereby providing diagnostic insights into specific areas requiring improvement. The combination of radial and slack movements within the DEA framework enables the computation of projected input-output values that would allow inefficient DMUs to become efficient under existing technological constraints.

The Two-Stage DEA approach offers several analytical advantages for this study. First, it distinguishes between efficiency losses arising from resource misallocation (Stage 1) and those resulting from systemic implementation inefficiencies (Stage 2). Second, it captures the multidimensional nature of stunting intervention programs, which integrate health, sanitation, and social welfare components. Third, it allows for policy-relevant benchmarking by identifying regions that demonstrate exemplary performance despite limited fiscal resources. The robustness of this approach has been supported by prior empirical applications in health economics, such as Basso et al. (2022) and Asante et al. (2023), who demonstrated that multi-stage DEA frameworks effectively capture the complexity of health service delivery systems. In this context, the method is well-suited to the Indonesian stunting program, where diverse inputs are interlinked through multi-sectoral implementation chains.

Ultimately, the methodological design of this research aims to generate empirical evidence on the comparative efficiency of local government stunting intervention systems in Central Java. The findings are expected to inform evidence-based policymaking by identifying not only which regions perform

efficiently but also how and why certain units succeed in translating inputs into improved nutritional outcomes. This systematic and data-driven assessment contributes to advancing efficiency-based health governance as a foundation for reducing stunting prevalence and promoting equitable child development across Indonesia.

RESULT AND DISCUSSION

Overview of Stunting Reduction Dynamics in Central Java

The findings reveal that the reduction of stunting in Central Java between 2019 and 2023 has shown a gradual yet uneven trajectory across districts and municipalities. The prevalence declined from 27.7 percent in 2019 to 20.7 percent in 2023, which marks an overall improvement but remains slightly above the World Health Organization's threshold of 20 percent. This indicates that Central Java has not yet achieved the optimal level of child nutrition outcomes expected from a province prioritized for national stunting reduction programs. The disparity between regions suggests that while some local governments have efficiently managed their health and nutrition interventions, others continue to face operational and systemic constraints. Differences in fiscal capacity, infrastructure quality, and health workforce distribution appear to significantly influence program effectiveness. Moreover, regions that performed efficiently were not necessarily those with the largest budgets but those demonstrating strong institutional coordination, effective monitoring, and consistent program implementation at the village level.

Empirical Results of Two-Stage DEA Analysis

The Two-Stage DEA model quantified the technical efficiency of each district and municipality in managing stunting interventions. The analysis identified that only Banjarnegara and Grobogan achieved perfect efficiency scores (1.000), implying that these regions operate at the best practice frontier in converting program inputs into nutritional outcomes. Most other districts obtained efficiency scores ranging between 0.65 and 0.89, indicating moderate inefficiency. The first stage, which focused on input efficiency, highlighted issues in the utilization of public health resources, particularly in programs related to exclusive breastfeeding, immunization, and maternal healthcare coverage. In several districts, the efficiency gap emerged because the resources allocated to nutrition interventions were not proportional to the improvements achieved in service coverage.

The second stage of analysis, which measured system efficiency, revealed weaknesses in translating improved health service coverage into tangible nutritional outcomes. Several regions recorded high coverage of basic health services yet continued to experience significant stunting prevalence. This condition reflects deficiencies in intersectoral coordination and behavioral aspects of nutrition practices, such as inadequate maternal knowledge, food insecurity, and poor sanitation habits. The DEA model's slack analysis showed that input excesses—particularly redundant spending on overlapping programs—were common, while output shortfalls pointed to limited impacts on nutritional status despite the presence of adequate health infrastructure. These results indicate that inefficiency in stunting programs is not solely due to a lack of financial resources but rather to ineffective system design and limited synergy among policy actors.

Spatial Disparities and Determinants of Efficiency

Spatially, the efficiency distribution reveals a clear pattern where mid-sized districts with balanced urban and rural populations tend to perform better than large urban centers or remote rural regions. Banjarnegara and Grobogan exemplify how integrated governance, effective use of community health workers, and consistent monitoring of household-level nutrition data can enhance efficiency. In

contrast, some industrial or densely populated areas exhibited inefficiencies due to fragmented program coordination and bureaucratic overlap among local agencies. The role of social determinants—such as poverty, education, and gender empowerment—was also found to be significant. Regions with stronger community-based empowerment programs and better maternal education levels tended to achieve higher efficiency in reducing stunting prevalence.

The results are consistent with prior empirical studies in developing contexts. Asante et al. (2023) found that managerial capacity and institutional coordination are stronger determinants of efficiency than financial expenditure alone. Similarly, Basso et al. (2022) and Hollingsworth (2008) emphasized that efficiency variations in public health programs often stem from structural and managerial disparities rather than resource availability. In Central Java's context, this suggests that improving efficiency requires not only increased budgetary support but also reforms in governance, data integration, and monitoring mechanisms.

Implications for Program and Policy Design

The findings carry several implications for policy reform and program management. First, enhancing efficiency demands better integration between nutrition-specific and nutrition-sensitive interventions. In Central Java, these two streams—medical and environmental—are often managed separately, leading to duplication and gaps. Consolidating these initiatives within a single district-level framework could streamline operations and reduce resource waste. Second, local governments need to adopt data-driven performance monitoring tools that align with efficiency principles. Routine evaluation using DEA or similar models can guide the reallocation of resources toward more effective activities and ensure accountability.

Third, capacity building for local health workers and community cadres is essential. Efficient regions demonstrate that human capital quality significantly affects program delivery outcomes. Training focused on counseling mothers, managing household nutrition, and improving sanitation practices can yield higher returns on investment than simply expanding program budgets. Fourth, long-term efficiency depends on addressing cross-sectoral linkages. Stunting cannot be effectively reduced through health interventions alone; improvements in water, sanitation, education, and social protection are equally critical. The government should therefore institutionalize intersectoral coordination platforms to align policies and budgets across ministries and local agencies.

Fifth, public health governance must incorporate performance-based budgeting systems. Rather than allocating funds solely based on population size or administrative divisions, resource distribution should consider empirical efficiency scores. Districts that demonstrate higher efficiency can serve as benchmarks for others, while those lagging can receive targeted technical assistance. This approach promotes equity and accountability while ensuring that fiscal transfers contribute to measurable health improvements.

Comparative Perspective and Theoretical Integration

From a comparative perspective, the Central Java experience resonates with efficiency studies in other developing regions. For example, Nadya and Atmanti (2022) reported similar patterns of regional inefficiency in national-level stunting programs, with significant variation among provinces. Their findings align with this study's conclusion that efficiency gaps often result from weak institutional coherence and insufficient cross-sectoral collaboration. The use of the Two-Stage DEA model in this research extends the theoretical framework of Farrell (1957) by incorporating multiple interrelated processes that better represent the reality of health program implementation.

Theoretically, the findings reinforce efficiency theory as a diagnostic framework for public policy analysis. Efficiency is not a static measure of resource utilization but a reflection of dynamic governance capacity. The results confirm that government units differ not only in technical capabilities but also in strategic coordination across program stages. The two-stage approach operationalizes this understanding by linking the management of inputs and the generation of outcomes. It underscores that the ultimate success of stunting reduction programs depends on how well local institutions transform administrative effort into societal impact.

Lastly, this study highlights the importance of balancing efficiency with equity. Although DEA effectively measures relative performance, it does not capture distributive fairness. Districts achieving high efficiency may still leave behind marginalized groups in remote areas. Therefore, policymakers must complement efficiency analysis with equity-oriented assessments to ensure that performance improvements contribute to inclusive child nutrition outcomes.

In summary, the discussion underscores that improving technical efficiency in stunting intervention systems requires an integrated, data-driven, and participatory approach. The Central Java case demonstrates that governance quality, human resource capacity, and intersectoral collaboration are the most decisive factors determining efficiency rather than the sheer volume of financial resources. These insights are critical for shaping Indonesia's broader strategy for sustainable human development and equitable health outcomes.

CONCLUSION

This study analyzed the technical efficiency of stunting intervention programs across 35 districts and municipalities in Central Java Province during the 2019–2023 period using a Two-Stage Data Envelopment Analysis (DEA) approach. The results revealed that overall program efficiency in the province remains suboptimal, with only Banjarnegara and Grobogan achieving full efficiency. Although the prevalence of stunting has declined from 27.7 percent in 2019 to 20.7 percent in 2023, the province has not yet reached the World Health Organization's benchmark of 20 percent. The persistence of inefficiencies indicates that the stunting reduction system in Central Java is constrained not only by resource limitations but also by institutional fragmentation, uneven program implementation, and inadequate coordination among stakeholders.

The findings highlight that the determinants of efficiency extend beyond financial input. Regions with stronger leadership, effective coordination between health offices and community cadres, and better integration of nutrition-specific and nutrition-sensitive programs tend to perform more efficiently. Conversely, inefficiency is often associated with overlapping interventions, redundant spending, and weak cross-sectoral collaboration. These results demonstrate that technical efficiency in public health interventions is primarily driven by governance quality and institutional adaptability rather than by resource magnitude alone.

From a theoretical perspective, the study reinforces the relevance of efficiency theory as an analytical framework for evaluating public health performance. The application of the Two-Stage DEA model provides a deeper understanding of both input utilization and systemic implementation efficiency, aligning with systems theory in public administration. By distinguishing between resource allocation efficiency and system output efficiency, this model offers a holistic assessment of how policy design and operational execution interact within the stunting reduction framework. The integration of efficiency measurement into health policy evaluation thus serves as an evidence-based mechanism for improving the accountability and effectiveness of public spending.

The implications of this research are multi-dimensional. First, improving efficiency requires strengthening intersectoral coordination between health, sanitation, education, and social welfare

programs. Policy integration and the establishment of unified monitoring systems are essential to prevent resource duplication and enhance coherence across interventions. Second, capacity-building initiatives for local health workers and village cadres must be prioritized to improve the delivery of nutrition services and community outreach. Third, continuous efficiency monitoring using DEA or similar models should be institutionalized within regional health planning to identify performance gaps and guide adaptive policy reforms. Finally, efforts to improve efficiency should be accompanied by a commitment to equity, ensuring that gains in performance translate into inclusive and sustainable health outcomes for all communities.

In conclusion, the reduction of stunting in Central Java—and by extension, Indonesia—requires a strategic shift from resource-intensive approaches to efficiency-oriented governance. Technical efficiency must be viewed not merely as a performance metric but as a policy instrument that informs evidence-based decision-making and equitable development. The results of this study underscore that sustainable progress in stunting prevention can only be achieved when resources, institutions, and communities are aligned toward a common goal of optimizing human development outcomes.

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Conflict of Interest

The authors declare no conflict of interest related to the publication of this study.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Author Contribution

All authors contributed equally to the design, data collection, analysis, and writing of this manuscript. All authors have read and approved the final version of the paper.

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