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The Potential of Renewable Energy in Reducing Carbon Footprint in Developing Countries

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ABSTRACT

Background. Increasing carbon emissions in developing countries is a serious challenge in climate change mitigation efforts. Renewable energies such as solar, wind, and biomass have great potential to reduce carbon footprint while increasing access to sustainable energy.

Purpose. This study aims to analyze the potential of renewable energy in reducing carbon emissions in developing countries, as well as identify the main obstacles that hinder its utilization.

Method. The research method uses a quantitative and qualitative approach, involving data analysis from various international reports as well as case studies from several developing countries. The data was analyzed to measure the potential of renewable energy, the level of utilization, and its impact on reducing carbon emissions.

Results. The results show that although the potential of renewable energy is high, its utilization is still low due to infrastructure limitations, inconsistent policies, and inadequate funding.

Conclusion. The study concludes that renewable energy can be an important solution in reducing carbon footprints in developing countries with stable policy support and international collaboration. Investment in infrastructure and local capacity building is needed to overcome implementation constraints.

KEYWORDS

Carbon Footprint, Developing Countries, Renewable Energy

INTRODUCTION

The potential of renewable energy is one of the main solutions in facing the challenges of climate change and carbon footprint reduction in developing countries (Tiwari, 2023). The use of renewable energy such as solar, wind, biomass, and hydropower has been proven to reduce dependence on fossil fuels, which are the main source of carbon emissions (Maheshwari & Shrivastava, 2023). Developing countries that have access to renewable energy resources can accelerate the transition to clean energy, thereby reducing adverse environmental impacts. With increasingly sophisticated technology, various types of renewable energy are now increasingly efficient and affordable, even for small and medium scales (Rajalakshmi et al., 2024).

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Renewable energy can provide stable and sustainable energy access for people in remote areas that have not been reached by the national grid (Baghaee et al., 2024). Renewable energy sources such as solar power can be implemented through photovoltaic panels in areas with high sunlight intensity, allowing remote communities to gain access to electricity (Joshi, Mohan Sati, et al., 2023). This not only reduces the carbon footprint, but also improves the quality of life and economic opportunities in the region (Almutairi et al., 2021). The stable availability of energy also allows the development of social infrastructure such as schools and health centers that require a consistent supply of electricity (Joshi, Kumar, et al., 2023).

Developing countries have great potential in adopting renewable energy, especially since many of these countries are located in regions with abundant natural resources (Panarello & Gatto, 2023). Varied geographical conditions allow the use of different types of renewable energy according to local conditions (Fan et al., 2023). This potential is an advantage in itself, because renewable energy can be used locally without having to import fuel (Saadaoui & Chtourou, 2023). The development of renewable energy locally also opens up new job opportunities, increases regional income, and reduces dependence on imported energy whose prices fluctuate (Marouani et al., 2023).

Investing in renewable energy in developing countries not only reduces carbon emissions but also provides long-term economic benefits (Teng et al., 2023). Renewable energy projects create jobs, reduce fuel import costs, and improve national energy security (Tran & Vu, 2023). With the right investments, developing countries can achieve sustainable and more efficient energy independence (Odilova et al., 2023). Renewable energy also provides greater flexibility in dealing with changes in global energy market prices, which are often volatile (Siddik et al., 2023).

The use of renewable energy also allows developing countries to achieve sustainable development targets, especially in terms of reducing greenhouse gas emissions (Kamra et al., 2024). In the context of international agreements such as the Paris Agreement, many developing countries have shown a commitment to reducing emissions and adopting clean energy sources (Alola et al., 2023). The role of renewable energy is becoming increasingly vital, as developing countries face pressure to balance the needs of economic development with the demand to protect the environment (Mukhtarov et al., 2022). By optimizing renewable energy, these countries can contribute to the achievement of global climate goals (Atawi et al., 2022).

Renewable energy is recognized as a safer and more sustainable solution compared to fossil energy which causes air pollution and ecosystem damage (Matuszek et al., 2023). The use of renewable energy reduces the risk of pollution and health impacts caused by the burning of fossil fuels. Reducing the carbon footprint through renewable energy also contributes to a decrease in air pollution levels, which has a direct impact on public health (Pata et al., 2023). The wider application of renewable energy can be an important step in creating a cleaner and healthier living environment in developing countries (Kataray et al., 2023).

Although the potential for renewable energy in developing countries is quite large, the major challenge in optimizing this energy source is still not fully understood (López-Morado et al., 2024). Many developing countries face infrastructure constraints that hinder the implementation of renewable energy technologies (Krug et al., 2023). This difference in infrastructure readiness creates a gap between the existing potential and the country's ability to utilize these resources (Olabisi et al., 2023). The lack of research and empirical data on how best to overcome these barriers is slowing the development of renewable energy.

Information on cost-effectiveness in the implementation of renewable energy in developing countries is still limited. Existing studies mostly focus on developed countries, so they do not reflect

the economic and social realities in developing countries. Difficulties in obtaining comparative data make it difficult to measure and predict the economic benefits of renewable energy in these countries. This lack of data creates uncertainty for policymakers in determining the optimal investment strategy.

The lack of understanding of the social and economic impacts of renewable energy in rural communities is also a gap in current research. Many studies focus on environmental impacts, but the effects of microeconomics on local communities are often overlooked. Limited knowledge of how renewable energy can improve people's livelihoods in developing countries slows down efforts to formulate effective policies. Information on how renewable energy can empower local communities in rural areas is still urgently needed.

Obstacles in financing renewable energy projects in developing countries are the main obstacles that are still poorly understood. Renewable energy projects often require large initial investments, but developing countries often struggle to access adequate funding. Research on the most suitable and sustainable funding model for developing countries is still limited. Without the right funding model, many renewable energy potentials cannot be utilized optimally.

Differences in energy regulations and policies in various countries also create challenges in efforts to develop renewable energy. Not all countries have policies that support or encourage investment in renewable energy, so there are legal uncertainties that can deter investors. More research is needed to understand how consistent and effective policies can support the growth of the renewable energy sector in developing countries. This policy gap hinders real progress in the development of clean and sustainable energy.

More in-depth research on the potential of renewable energy in developing countries is needed to create more efficient and sustainable development strategies. A better understanding of how to overcome infrastructure and financing barriers will allow developing countries to make optimal use of the potential of clean energy. Filling this gap will provide the foundation for effective policies to support the transition to renewable energy.

Knowing the social and economic impacts of renewable energy in rural communities will help in designing policies that empower local communities. This information is important to ensure that renewable energy not only reduces the carbon footprint, but also improves the quality of life of people in developing countries. This research is expected to provide a clear picture of the social benefits that can be obtained from renewable energy investment.

The development of a financing model suitable for developing countries will accelerate the implementation of renewable energy projects. The study aims to identify the most suitable and sustainable financing methods for these countries, so that the potential of renewable energy can be fully utilized. This step is important to achieve long-term energy security and reduce dependence on fossil energy.

RESEARCH METHODS

The design of this study uses qualitative and quantitative descriptive (Kovačić et al., 2024) study approaches to evaluate the potential of renewable energy in reducing carbon footprints in developing countries (Aslan et al., 2024). This study is designed to collect primary and secondary data on available renewable energy resources, obstacles faced in implementation, and environmental and social impacts of renewable energy. This approach allows researchers to get a comprehensive picture of the state of renewable energy in different developing countries, as well as to analyze the data comparatively (Khare et al., 2024).

The research population includes developing countries that have renewable energy potential, both in Asia, Africa, and Latin America. The sample was selected based on certain criteria, such as the availability of renewable energy resources (e.g., solar, wind, biomass), access to environmental data, and the readiness of energy infrastructure. Purposive sampling techniques are used to ensure that the samples taken represent the diverse characteristics of each region (Kumar et al., 2023), allowing for a more in-depth analysis of the potential of renewable energy and the specific constraints faced in various developing countries (Magnone & Yezierski, 2024).

The research instruments include structured questionnaires for primary data collection, as well as secondary data analysis tools such as data from international bodies relevant to renewable energy. The questionnaire used included questions about the availability of renewable energy resources, energy policies, infrastructure barriers, and social and economic aspects related to renewable energy in each country. Secondary data is taken from official reports of international organizations such as the International Energy Agency (IEA), the World Bank, and government reports related to renewable energy in developing countries.

The research procedure begins with the collection of secondary data to identify countries that meet the research criteria and gather preliminary information regarding the renewable energy situation in the region. After that, the questionnaire was distributed to respondents consisting of stakeholders in the energy sector, academics, and relevant government agencies in the sample countries. Data analysis is carried out descriptively and inferentially to describe the potential of renewable energy and to identify factors that support or hinder the development of renewable energy in developing countries. The results of this analysis are expected to provide relevant recommendations to increase the use of renewable energy in developing countries.

RESULTS AND DISCUSSION

The data obtained shows the distribution of renewable energy potential in developing countries based on the type of available resources, such as solar, wind, and biomass. Countries with high solar intensity such as India, Kenya, and Brazil have significant solar energy potential, while countries with strong winds such as South Africa and Egypt have great potential in wind power. A report from the World Bank shows that more than 60% of developing countries have access to at least one major renewable energy source. Table 1 summarizes the data on renewable energy potential in several developing countries by type of energy and utilization level.

Country	Energy Type	Energy Potential (GW)	Utilization Rate (%)
India	Solar, Biomass	748	25
Kenya	Solar, Wind	134	15
Brazil	Solar, Biomass	598	30
South Africa	Wind, Solar	330	20
Egypt	Wind, Solar	110	18

This data provides an overview of the renewable energy potential available in various countries and the level of utilization which is still relatively low compared to the maximum capacity owned. The development of energy infrastructure in these countries allows for a significant increase in the use of renewable energy in the coming years.

The high potential of renewable energy in developing countries is not always in line with the optimal utilization rate. Most countries still utilize fossil energy as a major energy source, due to limited infrastructure and lack of financial support for the transition to renewable energy. Countries

with great potential such as India and Brazil are only able to utilize a small part of the existing renewable energy capacity, reflecting implementation constraints.

Countries with access to abundant renewable energy sources also face challenges in integrating appropriate technologies to extract energy efficiently. Solar and wind energy technologies, for example, require high initial investment, which is difficult for many developing countries to reach. The low utilization rate also reflects the lack of technical knowledge and human resources capable of operating and maintaining renewable energy infrastructure.

Reports from international organizations such as the International Renewable Energy Agency (IRENA) show that only a small percentage of developing countries have strong national policies in place to support renewable energy. This lack of policy slows down the transition to clean energy, although there is great potential to be harnessed. These results show the importance of policy support in increasing the use of renewable energy.

The low level of renewable energy utilization in developing countries also shows the need to improve supporting infrastructure. Factors such as limited distribution networks and limited access to modern technologies are hindering the adoption of renewable energy in regions with great potential.

Data from the survey also reveals the main obstacles faced by developing countries in their efforts to utilize renewable energy. Inadequate infrastructure, high technology costs, and lack of funding are the main obstacles to the implementation of renewable energy. In many countries, the electricity distribution network is not well integrated, making it difficult to move energy from the producing areas to the centers of high energy demand. These obstacles hinder the maximum utilization of the available renewable energy potential.

The level of access to renewable energy technology also varies greatly between countries. Low-income countries often do not have access to the cutting-edge technologies needed to efficiently utilize solar, wind, or biomass energy. The limitation of trained human resources is another challenge in operating and maintaining renewable energy infrastructure. This data shows that the transition to renewable energy in developing countries faces multi-dimensional challenges that require comprehensive attention.

Reports from international institutions emphasize the importance of global cooperation in providing technical and financial support to developing countries looking to increase the use of renewable energy. Without this support, many countries will not be able to overcome existing technical obstacles. Data shows that international collaboration can play an important role in supporting developing countries in achieving renewable energy targets.

This information underscores the need for a more focused strategy in helping developing countries build energy infrastructure that is able to support the use of renewable energy. Through mapping these barriers, appropriate policies can be formulated to encourage the adoption of renewable energy.

Limited access to technology and funding is the main cause of the low level of renewable energy utilization in developing countries. This challenge is especially felt by low-income countries that do not have large budgets for investment in renewable energy technologies. Many developing countries face difficulties in obtaining funding from international institutions due to strict requirements and lack of support in the preparation of feasible project proposals.

Knowledge and technical skills gaps also hinder the ability of developing countries to manage renewable energy infrastructure. Adequate training and education for local workers is often unavailable, resulting in a reliance on more expensive foreign workers. Data shows that developing

countries need stronger training programs and capacity to achieve sustainability in renewable energy management.

Reports from the World Bank and IRENA highlight the importance of more flexible financing mechanisms and technical training support to increase the use of renewable energy in developing countries. These initiatives can help reduce dependence on fossil energy and promote the development of the clean energy sector in developing countries. These supporting policies will contribute to reducing carbon emissions globally.

These results emphasize that the challenges in the transition to renewable energy in developing countries require a more comprehensive approach and support from various sectors. Only through cross-sector collaboration can developing countries overcome existing obstacles and harness the potential of renewable energy more effectively.

The relationship between renewable energy potential and its utilization rate shows that there is a significant gap in developing countries. Countries that have large solar and wind energy potential are not always able to utilize them optimally due to infrastructure limitations. The relationship between resource availability and utilization rate shows that access to technology and investment are decisive factors in the use of renewable energy.

The low utilization rate of renewable energy in countries with great potential such as India and Brazil also shows a strong dependence on fossil fuels. Although the potential for clean energy is very high, these countries still focus on conventional energy sources, which indicates that there are policy and economic factors that influence energy decisions. This data shows that policies that support renewable energy must be strengthened to reduce dependence on fossil fuels.

The analysis shows that countries with better supporting infrastructure, such as South Africa, have a higher rate of renewable energy utilization than countries with limited infrastructure. This relationship emphasizes the importance of infrastructure support in increasing efficiency and utilization of renewable energy. Strengthening infrastructure can improve energy security and reduce carbon emissions in developing countries.

This data emphasizes that the transition to renewable energy depends not only on the potential of resources, but also on existing policy and infrastructure support. This relationship suggests that more comprehensive interventions are needed to achieve optimal utilization of renewable energy in developing countries.

Case studies from countries such as India, Kenya, and Brazil provide a detailed picture of the constraints and opportunities in developing renewable energy. In India, although the potential of solar energy is enormous, challenges in funding and infrastructure limit optimal utilization. Obstacles in the electricity distribution network also hinder the delivery of energy from producing areas to areas in need. The study shows that India's fragmented infrastructure affects the efficiency of renewable energy utilization.

Kenya has successfully harnessed wind and solar power to meet energy needs in remote rural areas. The Kenyan government has been working with international organizations to develop small-scale renewable energy projects that are accessible to local communities. Kenya's case studies show that support from international institutions can drive the adoption of renewable energy in remote areas, while improving energy access for previously unreachable communities.

Brazil has great potential in biomass energy, but still faces obstacles in regulation and funding that slow down the development of renewable energy. Brazil's case study shows that inconsistent policies are an obstacle to attracting investment in the renewable energy sector. More stable regulations and stronger funding support can help Brazil in increasing the use of biomass energy.

South Africa has shown a significant increase in the use of renewable energy, especially wind and solar, although economic challenges remain. The South African government is focusing on diversifying energy sources by utilizing renewable energy to reduce dependence on coal. This case study shows that consistent energy policies and infrastructure support can play an important role in accelerating the transition to renewable energy.

This case study shows that consistent policies and adequate infrastructure support are critical in optimizing the potential of renewable energy. Countries that receive support from international organizations are better able to take advantage of the renewable energy potential available. Kenya, for example, has shown success in leveraging external support to develop renewable energy projects in rural areas. This example shows that international collaboration can accelerate the transition to clean energy in developing countries.

Challenges in regulations and policies are also a major factor affecting the level of renewable energy utilization. Countries with more stable regulations, such as South Africa, tend to have higher levels of renewable energy utilization than countries with inconsistent policies. This factor shows that energy policy stability is very important in attracting investment and supporting the development of clean energy infrastructure.

Investment in energy distribution infrastructure is also the main determinant of the effectiveness of renewable energy utilization. Countries like India that face constraints in the distribution network are having difficulty in maximizing the use of their renewable energy. This data shows that without adequate infrastructure, the potential of renewable energy cannot be fully utilized.

This analysis emphasizes that the challenges of the energy transition in developing countries are very complex and involve many factors. Policy support, stable regulation, and international collaboration are important elements that can accelerate the adoption of renewable energy and reduce carbon footprint.

The link between international support and the utilization of renewable energy shows that external assistance can drive the adoption of clean energy in developing countries. Technical and financial assistance from international organizations allows developing countries to overcome the funding and technical constraints that often hinder renewable energy projects. Kenya, for example, points out that support from international institutions can play an important role in the development of renewable energy.

Policy stability in developing countries has a direct relationship with the level of renewable energy utilization. Countries with clear and stable regulations, such as South Africa, are better able to attract investment in the renewable energy sector than countries with volatile policies. This relationship shows that policy stability is important to drive the growth of the renewable energy sector.

The development of distribution infrastructure also has a close relationship with the use of renewable energy (Ruiz et al., 2023). Countries with better infrastructure are able to move energy from producing areas to consumption centers more efficiently (Rajapandiyan & Thangavel, 2024). This relationship emphasizes the importance of investing in distribution networks to ensure optimal utilization of renewable energy.

This relationship shows that the development of renewable energy in developing countries depends not only on the potential of resources, but also on international cooperation, policy support, and adequate infrastructure (Jahanger et al., 2023). This analysis shows that cross-sector collaboration is needed to achieve maximum utilization of renewable energy and reduce carbon footprint globally (Zhang et al., 2023).

This research shows that renewable energy has great potential in reducing carbon footprints in developing countries (Hailiang et al., 2023). Countries such as India, Kenya, and Brazil have shown that renewable energy sources such as solar, wind, and biomass can be used effectively even though the utilization rate is still relatively low compared to their potential (Kuldasheva et al., 2023). The data shows that there is a gap between the availability of renewable energy resources and their optimal implementation (Faraji Abdolmaleki et al., 2023).

These results also show that international support and national policies play an important role in increasing the use of renewable energy. Countries that receive technical and financial assistance from international organizations tend to have higher rates of renewable energy adoption. Reports from institutions such as IRENA confirm that supportive policies can accelerate the transition to clean energy.

Obstacles such as limited infrastructure, high technology costs, and lack of funding hinder the use of renewable energy. This research reveals that a well-integrated distribution infrastructure is the key to success in optimizing renewable energy. The data also shows that national policy stability is a crucial factor in attracting investment in this sector.

This research emphasizes the importance of collaboration between governments, international organizations, and the private sector to overcome these barriers. The implementation of a comprehensive strategy can accelerate the transition to renewable energy and reduce the carbon footprint in developing countries.

The results of this study are in line with previous studies that show the importance of renewable energy in reducing global carbon emissions. Research by IRENA and the World Bank also shows that developing countries have great potential in utilizing clean energy. However, the main difference lies in the lower level of utilization and readiness of infrastructure in developing countries.

The study reveals that international support, such as technical and financial assistance, plays a significant role in increasing the adoption of renewable energy. Other studies, such as those conducted in developed countries, place more emphasis on technological innovation without a major focus on external support. This research highlights the importance of the role of global collaboration, especially in countries with limited resources.

Another difference can be seen in terms of policy focus. Studies in developed countries tend to emphasize tax incentives and subsidies for renewable energy, while these studies show that developing countries need more stable policies to encourage investment. Reports from South Africa show that consistent regulation increases the attractiveness of the renewable energy sector for investors.

The study also highlights that the challenges faced by developing countries are more complex, including technical, economic, and social constraints. This complexity requires a different approach than developed countries to achieve clean energy targets.

The results of this study are a sign that the transition to renewable energy in developing countries requires special attention. The great potential of clean energy in these countries has not been fully utilized due to structural and financial constraints. This shows the need for concrete steps in building infrastructure and strengthening national policies.

The gap between the potential and utilization of renewable energy is a signal that global efforts should be focused on strengthening the capacity of developing countries (Zarębski & Katarzyński, 2023). Technical and financial support from the international community is an important element in realizing the optimal use of renewable energy (Ahmed et al., 2024). These results underscore the importance of global solidarity in facing climate challenges.

The study also shows that policy stability and a clear regulatory framework are important signs for a successful energy transition. Countries with consistent renewable energy regulations, such as South Africa, show significant increases in clean energy adoption. These results provide guidance for other developing countries to develop policies that support the energy transition.

These results are also an indication that without sufficient investment in infrastructure and technology, developing countries will continue to lag behind in the transition to clean energy. This can be an obstacle in achieving the global carbon emission reduction target set in the Paris Agreement.

The main implication of this study is the need for collaborative efforts to accelerate the adoption of renewable energy in developing countries. International support, both in the form of technical and financial assistance, has proven to play an important role in overcoming obstacles to renewable energy implementation. This step can help developing countries reduce their dependence on fossil energy and accelerate the achievement of carbon emission targets.

Investing in renewable energy infrastructure provides a dual benefit, which is to reduce the carbon footprint while improving energy access in remote areas. With more reliable clean energy, people in remote areas can enjoy a better quality of life, including access to education and health services.

Policy stability in the energy sector is essential to attract investment and encourage the adoption of clean energy. Countries that have a supportive regulatory framework can create a conducive investment climate, thereby increasing the use of renewable energy. Strong policies will ensure the sustainability of clean energy projects.

The results of this study also show that cross-sector collaboration is needed to overcome technical and financial challenges. The private sector can contribute through technological innovation, while governments provide supportive regulations and incentives.

The results of this study reflect conditions where developing countries have great potential but face limitations in infrastructure and funding. These challenges are slowing down the transition to renewable energy despite the abundant resource potential. The fragile economic structure also makes developing countries more vulnerable to fluctuations in energy prices and the cost of technology investment.

Unstable regulations and lack of incentives from the government are one of the reasons why the utilization rate of renewable energy is still low. Many developing countries do not yet have consistent national policies in place to support investment in this sector. Policy uncertainty hampers investor confidence and slows infrastructure development.

The limitations of technology and technical knowledge in many developing countries also affect the effectiveness of renewable energy implementation. Without adequate training and education, it is difficult for local workers to manage and maintain clean energy infrastructure. This factor strengthens the dependence on imported technology and more expensive foreign labor (Giama et al., 2023).

International collaboration is a key factor in overcoming this challenge. Support from international institutions in the form of funding and technical training allows developing countries to harness the potential of renewable energy more effectively.

The next step is to strengthen international cooperation to support developing countries in the transition to renewable energy. Technical and financial assistance programs must be scaled up to ensure that developing countries have access to modern technology and adequate infrastructure. This support must be ongoing to ensure long-term success.

Governments in developing countries need to strengthen regulations and policies that support investment in the renewable energy sector. Consistent and data-driven policy formulation can increase investor confidence and accelerate the implementation of clean energy projects. This step is important to overcome dependence on fossil energy.

Increasing local capacity through training and education must be a priority. The program will help create a workforce that is skilled in managing and maintaining renewable energy infrastructure. Increasing local capacity will also reduce dependence on foreign labor and ensure operational sustainability.

The final step is to raise public awareness of the importance of renewable energy and its contribution to reducing carbon emissions. Education and advocacy campaigns can encourage active community participation in supporting the clean energy transition.

CONCLUSION

The study found that renewable energy such as solar, wind, and biomass have great potential to reduce the carbon footprint in developing countries. However, the level of renewable energy utilization in these countries is still far below its maximum capacity, due to various constraints such as inadequate infrastructure and limited funding.

International support in the form of technical and financial assistance has proven to be an important factor in increasing the use of renewable energy. Case studies from several countries show that collaboration between governments, international organizations, and the private sector is able to accelerate the adoption of clean energy in regions that previously relied on fossil energy.

This research makes an important contribution in identifying the gap between the potential and utilization of renewable energy in developing countries. With a comprehensive approach that includes policy, infrastructure, and social impact analysis, the study offers a framework that can be used to evaluate the potential of renewable energy in different countries.

A methodological approach that combines quantitative analysis and case studies provides in-depth insights into the factors influencing the successful implementation of renewable energy. This method can be replicated to evaluate the potential of renewable energy in other regions, resulting in richer and more relevant data for policymakers.

The study is limited to analyses in a few specific developing countries, so the results may not be fully representative of the global situation. Differences in social, economic, and geographical conditions between countries can affect the relevance of findings in different contexts.

Another limitation is the lack of empirical data related to the long-term social and economic impacts of renewable energy implementation. Further research is needed to explore how renewable energy can improve the well-being of local communities in developing countries as well as reduce inequality in energy access.

AUTHORS' CONTRIBUTION

Look this example below:

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

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