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Designing a Geo-Edu Park through Structural Landform Analysis: Insights from Teletubbies Hill, Indonesia

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ABSTRACT

This study explores the geotourism potential of Teletubbies Hill in Wukirharjo Village, Yogyakarta, through detailed topographical and geomorphological mapping. Employing a terrestrial survey method using Total Station instruments, the research generates high-resolution elevation data to assess landforms and slopes shaped by ancient volcanic processes associated with the Semilir Supervolcano. Morphographic and morphometric analyses reveal that the site consists of structural hills with slopes ranging from 8% to 20%, categorized into two development zones based on slope steepness. The findings support the suitability of Teletubbies Hill for sustainable geotourism initiatives that combine education, recreation, and conservation. Proposed developments include the construction of a geological museum and an outdoor geological park to highlight the region's volcanic heritage and geological features. This integrated approach offers a framework for transforming underutilized landscapes into educational geotourism destinations. While the reliance on terrestrial methods limits broader geological context, future research could incorporate remote sensing and socio-economic feasibility assessments to enhance planning outcomes.

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INTRODUCTION

The integration of geological heritage into tourism development has gained increasing global attention as a pathway toward sustainable and educational tourism (Romera et al., 2024; Yazdi et al., 2024). Geotourism, as an emerging niche, not only promotes the appreciation of earth sciences but also enhances local economies and conservation efforts by transforming natural landscapes into sites of learning and recreation. In this context, topographical and geomorphological mapping plays a critical role in identifying and managing geotourism potential, especially in geologically rich but underutilized areas.

Teletubbies Hill, located in Wukirharjo Village, Prambanan District, Sleman Regency, Yogyakarta Special Region, exemplifies such a landscape. Geologically, this region lies within the Southern Mountains of Java, influenced by the ancient volcanic activity of the Semilir Formation. The area exhibits structural landforms formed through tectonic uplift and volcanic deposition, particularly from the Semilir Ancient Supervolcano. Despite its distinctive geological features, the site has remained largely overlooked in tourism development strategies. This neglect represents a missed opportunity, as such landscapes offer high educational and recreational value when developed as geotourism destinations (Drinia et al., 2023)

The growing body of research underscores the importance of geotourism in promoting sustainable regional development. According to Mutumba et al. (2025) sites with unique geomorphological and geological characteristics should be prioritized in tourism planning, provided there is a strong emphasis on environmental education and heritage interpretation. Moreover, research by Bankole et al. (2025) and Kadyrbekova et al., (2024) has shown that combining scientific knowledge with local culture and accessibility enhances the attractiveness and functionality of geotourism sites. Yogyakarta, as a leading tourism region in Indonesia, presents both the demand and institutional support required to incorporate geotourism into its broader tourism portfolio.

In areas with moderate to steep slopes and active tectonic histories, topographic mapping becomes especially vital or planning. Contour-based mapping allows planners to understand elevation patterns, identify risk-prone zones, and

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determine suitable locations for infrastructure and visitor engagement (Sufi et al., 2024). In particular, terrestrial surveying methods using Total Station instruments have proven effective in producing high-resolution topographic maps suitable for localized tourism planning (Stadnikov et al., 2025). When combined with morphographic and morphometric analysis, such mapping supports the categorization of landforms and the design of tourism elements in harmony with natural features (Zakaria & Hua, 2024).

This study aims to conduct a comprehensive topographical and geomorphological assessment of Teletubbies Hill using terrestrial mapping techniques to identify its geotourism potential. By integrating spatial data with landform analysis, the research seeks to develop a geotourism development framework that supports the creation of a Geo-Edu Park. This proposed site will serve as an educational and recreational space where visitors can learn about the region's volcanic history, geological structures, and tectonic processes. Ultimately, this study contributes to geotourism scholarship by offering a practical approach for developing sustainable geological attractions in volcanic regions of Southeast Asia.

METHODOLOGY

This study was conducted using a structured terrestrial mapping approach to evaluate the geotourism potential of Teletubbies Hill, a volcanic landform located in Wukirharjo Village, Prambanan District, Sleman Regency, Yogyakarta. The total surveyed area spanned approximately 10,500 square meters, characterized by undulating topography and elevations ranging from 165 to 275 meters above sea level.

The process began with a preliminary site analysis and field reconnaissance to determine the most appropriate locations for control points and station setup. A Leica TS-09 Plus Total Station was selected as the primary instrument for its high angular and distance measurement precision. A GNSS receiver was used to establish the initial control point and align the survey with Indonesia's national geodetic reference system (Bramanto et al., 2024). The team designed a closed-polygon traverse network consisting of eight observation stations, as shown in Figure 1. This layout enabled error detection and internal adjustment by ensuring that the starting and ending points were the same, thus forming a closed loop.

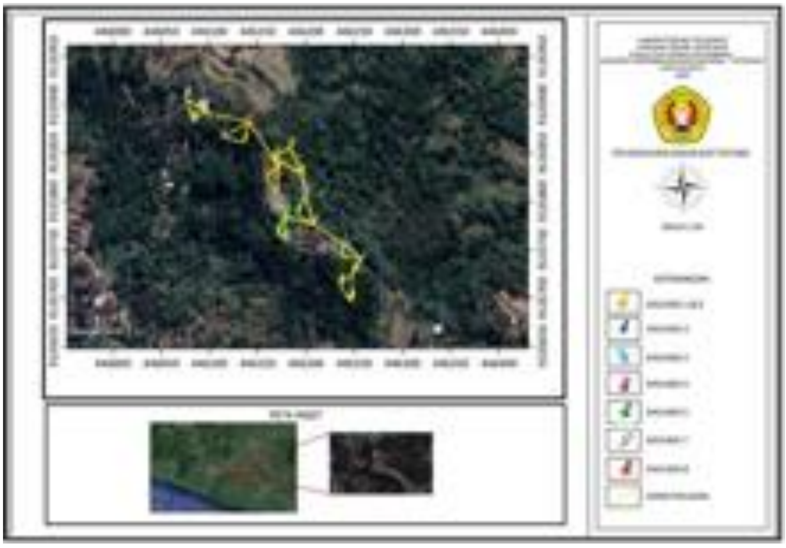

Figure 1. Survey Design

Each station collected horizontal and vertical angle measurements in both direct and reverse positions. Slope distances between stations were recorded in multiple readings to ensure consistency. After establishing the traverse, detailed mapping was carried out using radial shots to capture topographic features such as ridgelines, terraces, slope breaks, drainage channels, and existing infrastructure. In total, 1,214 points were surveyed, providing a dense dataset for modeling the terrain.

Following data collection, the traverse was adjusted using the Bowditch method to minimize angular and distance misclosures. Slope distances were reduced to horizontal distances, and orthometric heights were calculated using corrections from the EGM 2008 geoid model. The coordinate data were processed in ArcGIS Pro to generate a Triangulated Irregular Network (TIN), from which a Digital Elevation Model (DEM) with 0.5-meter resolution was created. Contour lines at five-meter intervals were derived from the DEM and smoothed for cartographic clarity. The resulting topographical map is presented in Figure 2, illustrating elevation patterns and terrain structure.

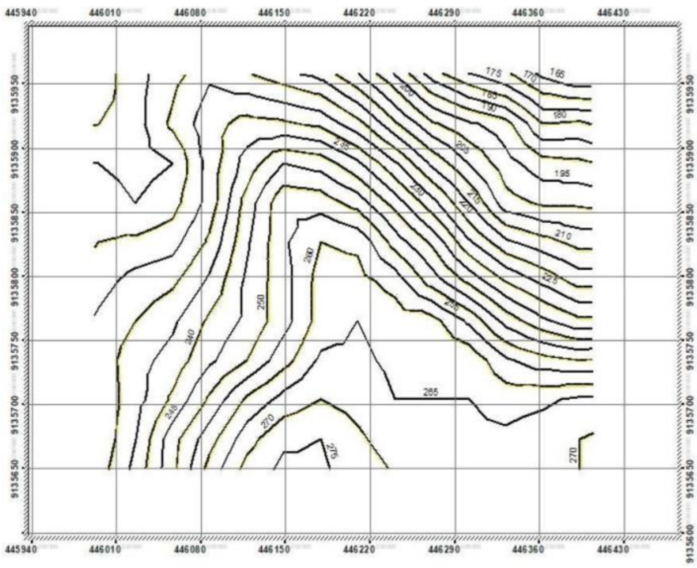

Figure 4. Topographical Map

The topographic data formed the basis for geomorphological analysis, which was performed in two stages: morphographic and morphometric classification. The morphographic assessment followed Lima et al. (2024) geomorphological framework, which classifies landforms based on their shape and origin. The site was dominated by structural hills—landforms influenced by tectonic uplift and volcanic activity. The morphometric analysis involved extracting slope values from the DEM and categorizing them based on steepness. The terrain was classified into two main slope units: S1 (steeper slopes, 14–20%) and S2 (moderately sloped areas, 8–13%).

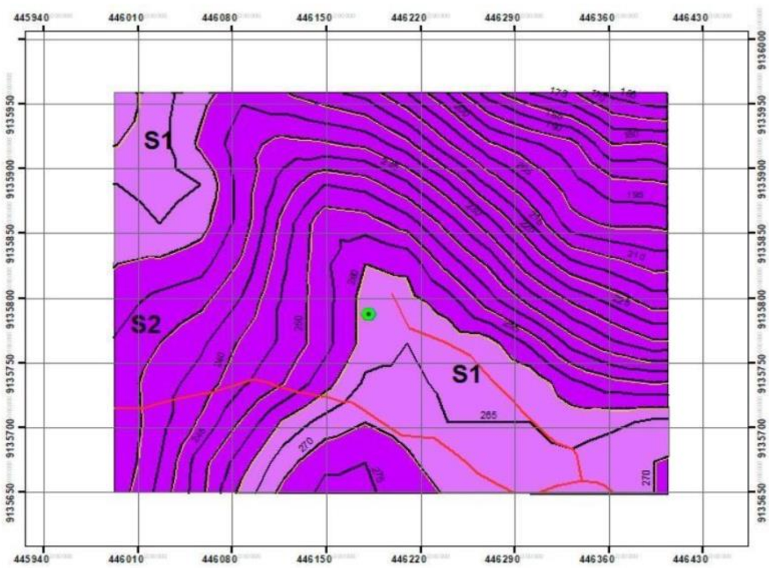

Figure 5. Geomorphological Map

The final geomorphological map is presented in Figure 3, where the structural units are overlaid on the contour base. S1 is primarily located along the ridgelines and steeper upper slopes, while S2 occupies the broader, more stable terrain on the lower and central parts of the hill. These classifications played a critical role in determining suitable zones for infrastructure development and visitor access in the proposed geotourism plan.

To ensure the integrity of the measurements, all instruments were calibrated before use, and repeated observations were taken at each setup. While the terrestrial method provided high-resolution data for accessible terrain, limitations arose in areas where line-of-sight was obstructed by dense vegetation or steep ravines. These gaps highlight the need for future surveys using UAV-based photogrammetry or airborne LiDAR to enhance coverage and detail, particularly in less accessible regions.

RESULT

Overview of Surveyed Terrain

The topographic survey conducted on Teletubbies Hill covered an area of approximately 10,500 square meters located within the Southern Mountains geomorphic zone of Yogyakarta. The terrain exhibits a combination of moderate to steep slopes, shaped by tectonic uplift and ancient volcanic activity from the Semilir Supervolcano system. Elevation values across the study area range from 165 meters above sea level at the northeastern base to 275 meters at the southwestern peak, forming a gradient of 110 meters within a relatively compact land parcel.

Initial field observations revealed a terrain dominated by ridgelines, slope breaks, and terraced slopes, some of which were anthropogenically modified for erosion control and land use purposes. The natural vegetation cover is interspersed with bare patches and minor agricultural activity, while a small number of built structures already exist on flatter terrain near the central portion of the site. These features informed the design of the closed-polygon traverse used during data collection.

From a geospatial perspective, the site demonstrates a high degree of vertical variability within a short horizontal distance, making it a suitable candidate for detailed morphometric and geomorphological analysis. This variability is critical in geotourism planning, as slope and elevation influence both aesthetic appeal and development feasibility. The next sections present the derived maps and analyses that capture this terrain complexity in detail.

Topographical Mapping

The processing of terrestrial survey data produced a detailed topographical map of Teletubbies Hill, as shown in Figure 2. This map was derived from 1,214 spatial data points collected using radial observations from eight total station setups within a closed-polygon traverse network. The contour lines on the map were generated at 5-meter intervals, accurately representing variations in elevation across the site.

The topographic surface reveals significant elevation differences, with contours clustering tightly along the southwestern section, indicating steep slopes, and widening toward the northeast, indicating more gradual terrain. The steepest areas, concentrated along the upper ridges and flanks, correspond to elevation values ranging between 245 and 275 meters above sea level. In contrast, the northern and central portions of the site display more spaced contours, representing gentler slopes between 165 and 220 meters in elevation.

The overall pattern of the contours suggests a hill with an asymmetric slope distribution. The eastern and northeastern slopes are broader and more accessible, while the western slopes are shorter but steeper. This pattern aligns with the geological origin of the hill, which is believed to be a structural landform formed from volcanic deposits shaped by uplift and differential erosion.

The contour map also indicates several slope transitions, terraces, and benches that may have been formed by both natural geomorphic processes and human intervention. These areas, particularly the flatter bench near 260 meters elevation, offer promising zones for infrastructure development due to their moderate gradient and strategic visibility.

From a geotourism planning perspective, the topographical map serves as a critical base layer. It enables slope classification, informs zoning decisions, and supports hazard assessment. Areas with lower slope gradients are more suitable for constructing visitor facilities, while steeper areas are better suited for scenic viewpoints or conservation purposes. The elevation data also contributes to identifying paths of least resistance for future access trails and ensuring safe and efficient visitor circulation.

Figure 2 provides a visual synthesis of these findings, highlighting the spatial variability in elevation and the contour-based delineation of terrain units that form the foundation for further geomorphological analysis and site planning.

Geomorphological Characterization

Following the generation of the topographical model, a geomorphological analysis was conducted to classify the landforms and evaluate their implications for geotourism development. This analysis was carried out using two approaches: morphographic interpretation based on landform shape and origin, and morphometric analysis based on slope quantification. Together, these methods provided a comprehensive understanding of the terrain's structural characteristics.

Morphographically, the study area is dominated by structural hills, which are characteristic of the Southern Mountains geological zone. These landforms were shaped primarily by endogenous processes—tectonic uplift, folding, and long-term erosion resulting in an asymmetric hill structure. The crest of Teletubbies Hill shows clear evidence of this structural origin, marked by elongated ridgelines and sharp slope transitions.

The morphometric analysis, derived from the Digital Elevation Model (DEM), classified the slopes into two major categories slope gradient classification system. The gentler slopes, ranging from 8% to 13%, were designated as Structural Unit S2, while the steeper slopes, between 14% and 20%, were identified as Structural Unit S1. These classifications are spatially mapped in Figure 3, which overlays the slope units on the topographical base map.

S2 occupies the western and northern flanks of the hill, characterized by broader and more stable terrain. This unit is well-suited for development due to its lower slope angle, reduced erosion risk, and easier access. Conversely, S1 encompasses the southern and eastern portions of the hill, where slope gradients are significantly steeper and contour lines are closely packed. This unit, while less ideal for infrastructure, offers panoramic views and natural scenic value, making it suitable for low-impact tourism interventions such as observation decks and guided geological trails.

The classification into S1 and S2 not only reflects variations in terrain steepness but also highlights areas of functional differentiation in land use potential. The physical distinction between these units provides a practical framework for zoning the hill into development and conservation areas. This geomorphological understanding ensures that site planning respects natural constraints while maximizing visitor experience and safety.

The presence of structural landforms and distinct slope units supports the hill's suitability as a geotourism destination. It allows for the integration of educational elements—such as interpretive signage explaining volcanic and tectonic processes—into the visitor experience. The geomorphological map shown in Figure 3 thus serves as a foundational reference for identifying site-specific opportunities and limitations for geotourism infrastructure and programming.

Site Suitability and Development Zoning

The integration of topographical and geomorphological analysis allowed for the delineation of site suitability zones across Teletubbies Hill, which directly informed the planning of geotourism infrastructure. The development zoning process considered multiple spatial factors, including slope gradient, elevation, landform classification, and accessibility. The aim was to identify areas that could support educational, recreational, and interpretive functions while minimizing environmental impact and ensuring visitor safety.

The slope classification served as the primary constraint in determining buildable versus non-buildable zones. As identified in the previous section, Structural Unit S2, characterized by gentler slopes of 8% to 13%, emerged as the most appropriate area for infrastructure development. This unit offers relatively stable terrain, easier construction logistics, and greater safety, particularly for accommodating high visitor foot traffic. In contrast, Structural Unit S1, with steeper slopes of 14% to 20%, was designated as a conservation and low-impact activity zone due to its susceptibility to erosion and its visual prominence in the landscape.

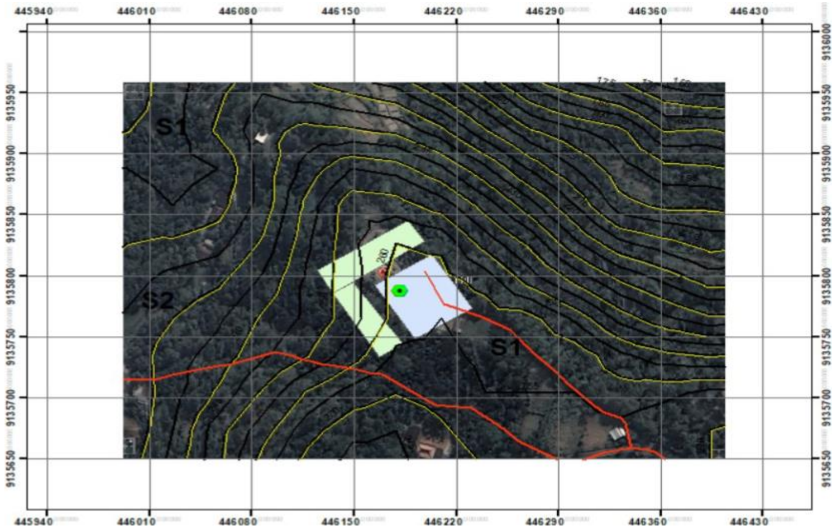

Figure 4. Development Zoning

Using this spatial foundation, a site development plan was created, shown in Figure 4. This map displays the proposed zoning layout, including access roads, pedestrian paths, and core facilities. The central highlight of the plan is the Geo-Edu Museum, strategically located on a flat bench at approximately 260 meters elevation within the S2 zone. This location was selected for its commanding views of the surrounding structural landforms, its accessibility from the main path, and its potential to serve as both a visitor center and an interpretive learning space.

Surrounding the museum, the plan incorporates designated green buffer zones and open spaces to preserve natural slope features while supporting light recreational use. These areas can serve as rest zones or outdoor classrooms, offering guided interpretation of volcanic rocks and tectonic processes visible on the surface. To the south and southeast, where steeper slopes dominate, the layout includes a looped interpretive trail network traversing Structural Unit S1. This trail is designed to provide panoramic viewpoints, rock exposure stops, and QR-coded educational panels highlighting the site's geodiversity and formation history.

Access to the site is facilitated through an existing rural road, marked in red in Figure 4, which connects the lower elevation areas to the development zone. This route minimizes the need for extensive road construction and aligns with sustainable tourism principles by reducing land disturbance. The proposed circulation pattern ensures a one-way visitor flow, reducing congestion and enabling better management of visitor experience.

By aligning infrastructure placement with slope classes and geomorphological zones, the development plan ensures that construction and visitor use remain within the landscape's carrying capacity. The separation of high-activity and conservation areas allows for the coexistence of tourism development and environmental stewardship. Furthermore, the plan enhances the interpretive potential of the site by leveraging the unique geological features of Teletubbies Hill.

The spatial zoning presented in Figure 4 demonstrates how scientific mapping and terrain analysis can directly inform geotourism planning. It provides a practical model for future site development that emphasizes both educational value and sustainability.

DISCUSSION

The findings of this study demonstrate how integrated topographical and geomorphological analysis can form a solid foundation for geotourism development planning in volcanic landscapes. Teletubbies Hill, situated within the tectonically active Southern Mountains of Yogyakarta, represents a case where geological significance intersects with tourism potential. Through the use of terrestrial mapping techniques and spatial classification, this study has outlined an evidence-based development plan that balances education, conservation, and visitor engagement.

The elevation and slope variability across Teletubbies Hill align with characteristics identified in other geotourism studies involving volcanic landforms (Zakaria & Hua, 2024). The structural differentiation into S1 and S2 zones mirrors successful zoning strategies adopted in global geoparks, where flatter terrain is prioritized for infrastructure and steeper terrain is reserved for scenic trails or educational signage (Grzeskowiak & Maciejko,

2024) In the present study, S2's moderate slopes (8–13%) were found most suitable for the proposed geological museum, supporting existing literature emphasizing slope stability as a critical factor in sustainable tourism site design (Rajendra Kumar et al., 2024).

The morphometric classification not only aids in hazard assessment but also adds interpretive value. For example, the elevation contrast between the Southern Mountains and the Yogyakarta depression zone provides a visual learning opportunity for visitors, reinforcing the link between landscape and geological process. This aligns with Sabila et al. (2024) emphasis on the "geological story" as central to effective geotourism experiences. The site plan presented in this study incorporates this principle by designing interpretive trails and visual viewpoints along structural ridgelines where tectonic uplift and volcanic history are physically observable.

Moreover, the use of terrestrial mapping methods like Total Station—though limited in coverage compared to UAV or LiDAR surveys—proved adequate for site-scale planning. This supports previous findings that high-resolution ground-based surveys remain valuable in areas with limited drone access or legal constraints (Frid & Frid, 2024). The closed-polygon traverse allowed for controlled accuracy and provided sufficient data density for digital elevation modeling and terrain classification.

The development framework proposed here also responds to global calls for more sustainable and context-aware tourism infrastructure. The strategic use of existing access routes, slope-informed zoning, and the conservation of steep slopes for non-invasive interpretation reflects the principles outlined by UNWTO and UNESCO for heritage site protection. It shows that geotourism planning can be not only site-specific but also aligned with broader sustainability goals such as environmental conservation, visitor safety, and local community engagement.

However, there are limitations that must be acknowledged. The study area's steep ravines and vegetated slopes restricted visibility and data acquisition in certain zones, potentially excluding microtopographic features of ecological or geological interest. Future research could incorporate UAV photogrammetry or LiDAR scanning to address these gaps and refine the site model. Additionally, this study focused primarily on physical geography, leaving socio-economic and cultural dimensions of tourism development for future assessment. Community perspectives, visitor preferences, and economic feasibility analyses will be essential to ensure that the site plan is not only physically viable but also socially and economically sustainable.

In conclusion, this study offers a replicable methodology for translating geomorphological and topographical data into functional tourism development plans. The case of Teletubbies Hill illustrates how scientific mapping can directly inform zoning, infrastructure siting, and visitor experience design in geotourism. It emphasizes that successful geotourism must be grounded in geological reality while remaining sensitive to landscape capacity, conservation needs, and educational value.

CONCLUSION

This study has demonstrated the effectiveness of integrating topographical and geomorphological mapping for sustainable geotourism planning at Teletubbies Hill, Wukirharjo Village, Yogyakarta. Through terrestrial surveying and digital elevation modeling, the terrain was accurately represented and classified into slope-based structural units (S1 and S2), forming the foundation for a spatially informed development strategy. The results highlight the value of S2's moderate slopes for infrastructure, such as a geological museum, and the suitability of S1's steeper zones for interpretive trails and panoramic viewpoints.

The research underscores the potential of combining physical landscape analysis with geotourism principles to create educational and environmentally sensitive visitor experiences. The proposed site plan reflects a balance between development and conservation, supporting the region's natural heritage while ensuring visitor accessibility and safety.

Despite the strengths of the approach, limitations remain particularly in the restricted visibility of steep or vegetated areas, which may require future UAV or LiDAR integration. Additionally, social and economic dimensions of geotourism development were not addressed in this study and warrant further exploration.

Overall, this research contributes a replicable planning model for volcanic geotourism destinations and offers strategic insights for developing Teletubbies Hill into a sustainable Geo-Edu Park grounded in geological authenticity.

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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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