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Aerodynamic Investigation of Motorcycle Windshield Design at Different Height Configurations

Muhammad Arif Marzuki[1], Mohammad Fahmi Abdul Ghafir[1]*

[1] *Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA*

*Corresponding Author: fahmi@uthm.edu.my
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Abstract

The objective of this study was to investigate how variations in motorcycle windshield height influence aerodynamic flow, drag coefficient, and rider comfort, and to determine the relationship between windshield height and drag coefficient. Three windshield height configurations were examined using computational fluid dynamics (CFD) simulations in Ansys Fluent, with geometry modeled in SolidWorks 2023: Model 1 (205 mm), Model 2 (250 mm), and Model 3 (330 mm). Simulations were conducted at operating speeds of 110, 140, and 160 km/h. Variations in drag coefficient with velocity were assessed, and static pressure fields on the rider were also evaluated. The results show that lower windshields produce less aerodynamic drag, with Model 1 yielding the lowest drag coefficient. Pressure-contour analysis further indicates that taller windshields reduce the overall pressure experienced by the rider. These findings demonstrate the significant role of windshield height in motorcycle aerodynamics and rider comfort and may support riders and manufacturers in optimizing motorcycle performance while improving the riding experience.

1. Introduction

Motorcycles are a widely used mode of transportation in Malaysia and other Asian countries, including Indonesia, Thailand, and Vietnam. In Malaysia, motorcycles have consistently represented a substantial proportion of registered vehicles and road users [1]. This high level of motorcycle use highlights the need to improve motorcycle performance, rider comfort, and stability under practical riding conditions. In recent decades, aerodynamic improvements have become increasingly important in surface-vehicle design because they influence drag, stability, fuel efficiency, and overall vehicle performance [2], [7].

Aerodynamic design can improve the performance of many vehicle types, including cars, trucks, and motorcycles. However, the aerodynamic requirements differ according to vehicle function and operating conditions. For example, race cars benefit from negative lift for cornering stability, whereas motorcycles are particularly sensitive to airflow separation, rider position, windshield configuration, and crosswind effects [2], [5]. Motorcycle windshield design is therefore important because it affects both the airflow around the motorcycle and the pressure experienced by the rider [2], [4], [7].

The drag force acting on a rider can cause discomfort during long-distance riding. Without a windshield, the rider is more directly exposed to incoming airflow, insects, debris, and road particles that may strike the helmet, face, or clothing. Direct wind exposure may also contribute to helmet buffeting, which occurs when unsteady airflow impinges on the helmet and produces vibration and instability. Previous motorcycle aerodynamic studies have shown that aerodynamic kits and windshield configurations can modify the flow field around a rider and influence drag, pressure distribution, and comfort [3], [4]. Strong aerodynamic forces acting on the motorcycle-rider system may also affect vehicle stability, particularly at higher speeds [5].

This study was motivated by the need to examine how different windshield height configurations affect motorcycle aerodynamics and rider experience. Understanding the relationship between windshield height, wind pressure, airflow disturbance, drag coefficient, and rider comfort is important for both riders and motorcycle manufacturers. Previous studies have shown that windshield geometry and rider position influence motorcycle aerodynamic performance [2], and that drag reduction through windshield design can improve rider comfort [4]. Related work on motorcycle windshield slot design also indicates that windshield modifications can improve aerodynamic characteristics [7]. Therefore, this study investigates how three windshield heights affect aerodynamic flow and drag coefficient at different motorcycle speeds, with the aim of establishing the correlation between windshield height and drag coefficient.

2. Methodology

This study was designed to investigate the effect of motorcycle windshield height on aerodynamic performance and rider exposure to airflow. The methodology consisted of several main stages: selection of the motorcycle and windshield configurations, three-dimensional geometry modelling, computational domain preparation, mesh generation, CFD simulation setup, solution execution, and post-processing of the aerodynamic results. CFD was selected because it has been widely used in motorcycle aerodynamic investigations to predict flow structures, pressure distribution, and aerodynamic forces around complex motorcycle-rider geometries [8]. Fig. 1 shows the research flowchart for the project.

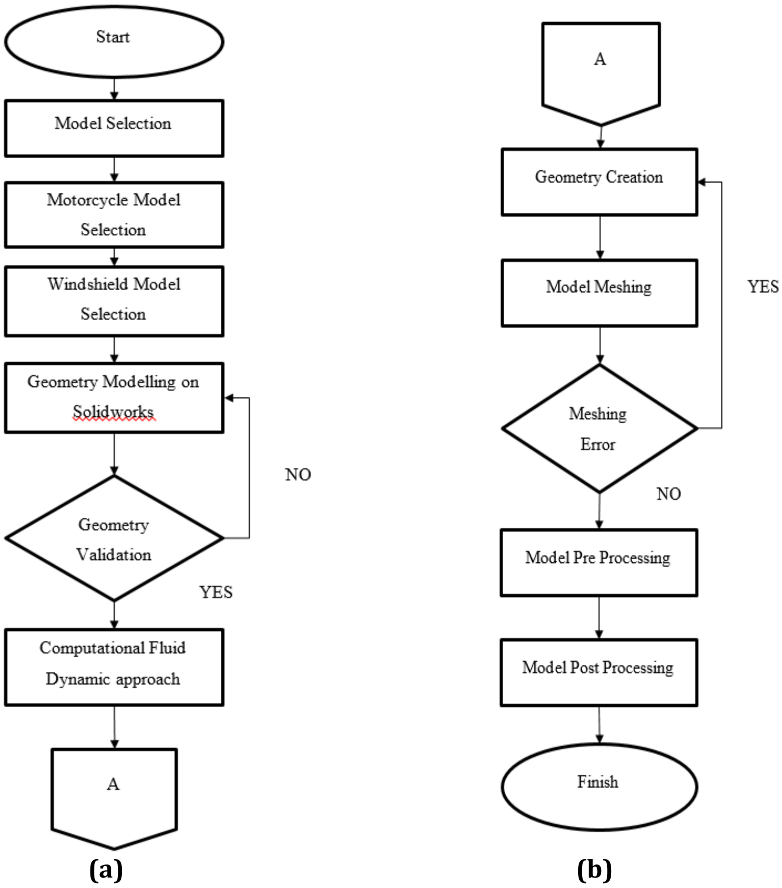

Fig. 1 *Research flowchart*

2.1 Geometry Modelling

After the motorcycle model and windshield configurations were selected, the three-dimensional geometry of the Kawasaki Versys 650 with rider was developed using SolidWorks 2023. The model was created at full scale with a 1:1 ratio, and all dimensions were specified in millimetres. To ensure a consistent comparison among the cases,

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the motorcycle and rider geometry were kept constant, while only the windshield height was varied. This modelling approach is consistent with motorcycle aerodynamic studies in which windshield geometry and rider position are treated as important parameters affecting aerodynamic performance [2].

Three windshield configurations were developed for the analysis. Model 1 used a windshield height of 205 mm, Model 2 used a windshield height of 250 mm, and Model 3 used a windshield height of 330 mm. These configurations are summarized in Table 1 and shown in Figs. 2-4. By varying only the windshield height, the aerodynamic influence of windshield height could be examined independently while maintaining the same motorcycle body geometry and rider posture.

Table 1 *Windshield heights of motorcycle models*

Model	Value
Model 1	205 mm
Model 2	250 mm
Model 3	330 mm

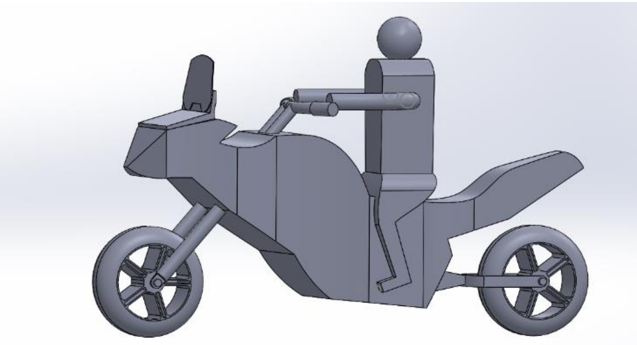

Fig. 2 *Model 1*

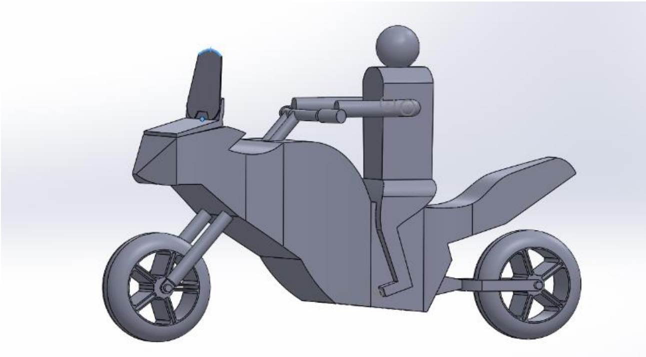

Fig. 3 *Model 2*

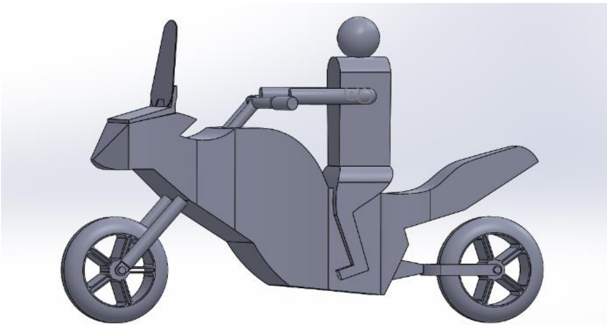

Fig. 4 *Model 3*

2.2 Computational Fluid Dynamics Approach in Ansys Fluent

The aerodynamic analysis was carried out using Ansys Fluent. Computational fluid dynamics (CFD) was employed because it enables numerical prediction of airflow behavior, pressure distribution, and aerodynamic forces around complex vehicle geometries. CFD has been applied effectively in motorcycle aerodynamic investigations because it provides detailed information on three-dimensional flow fields that is difficult to obtain from simple analytical methods alone [8]. The CAD models developed in SolidWorks were imported into Ansys Fluent for pre-processing, meshing, simulation, and post-processing. A computational domain was generated around the motorcycle and rider model to represent the surrounding airflow region. The geometry was then discretized into a finite-volume mesh, as shown in Fig. 5. The meshing process was performed carefully to capture the main flow features around the windshield, motorcycle body, and rider, particularly in regions where flow separation and pressure changes were expected.

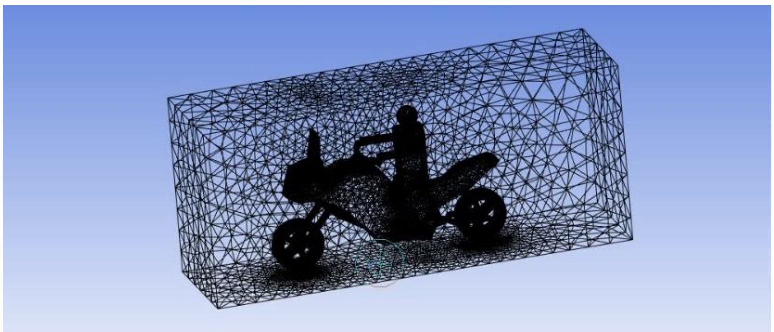

Fig. 5 *Meshing of the model*

The simulation was conducted using air as the working fluid. The inlet velocity was defined according to the selected motorcycle operating speeds of 110, 140, and 160 km/h. The standard k-epsilon turbulence model was selected to represent turbulent airflow around the motorcycle. The reference area used for the aerodynamic coefficient calculation was 1.40 m^2. The main operating conditions used in Ansys Fluent are listed in Table 2.

Table 2 *Operating conditions used in Ansys Fluent*

Parameter	Value
Units	km/h
Viscous model	k-epsilon
Materials	air
Velocity magnitude (km/h)	110, 140, 160
Reference value (Area)	1.40

2.3 Solution Method

The pressure-velocity coupling in the CFD simulation was solved using the SIMPLE algorithm. This method is suitable for steady-state incompressible flow problems and is commonly applied in external aerodynamic simulations. The solver settings used for the simulation are shown in Fig. 6. After defining the boundary conditions, material properties, turbulence model, and solution method, the simulations were executed for each windshield configuration and operating speed.

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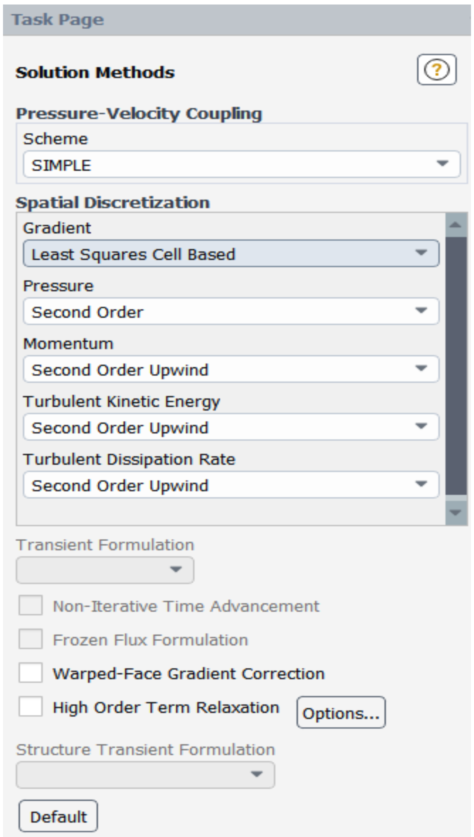

Fig. 6 *Solver settings for the solution method*

The computed results were processed to obtain the drag coefficient, velocity vectors, and static pressure contours. These outputs were used to compare the aerodynamic performance of the three windshield designs and to assess the pressure distribution acting on the rider. The analysis focused on the relationship between windshield height and aerodynamic drag, as well as the trade-off between reduced drag and rider wind protection [2], [4].

3. Results and Discussion

This section presents and discusses the aerodynamic performance of the three motorcycle windshield configurations. The analysis focuses on the drag coefficient, velocity characteristics, and static pressure distribution around the motorcycle and rider. The purpose of the comparison is to evaluate how windshield height influences aerodynamic drag and rider exposure to wind pressure under the same operating conditions. The drag coefficient is an important indicator of aerodynamic efficiency because it reflects the resistance generated by the interaction between the body shape and the surrounding airflow [5], [6]. A lower drag coefficient indicates that airflow passes around the vehicle with less resistance, whereas a higher drag coefficient indicates greater resistance caused by increased flow separation, pressure drag, or effective frontal area.

3.1 Correlation between Windshield Height and Drag Coefficient at Different Speeds

Fig. 7 shows the variation in drag coefficient for the three windshield configurations at speeds of 110, 140, and 160 km/h. The results indicate that the drag coefficient increases as the motorcycle speed increases for all three models. This trend is consistent with aerodynamic theory, in which higher travelling speeds increase the dynamic pressure acting on the motorcycle and rider, resulting in greater aerodynamic resistance [5], [6].

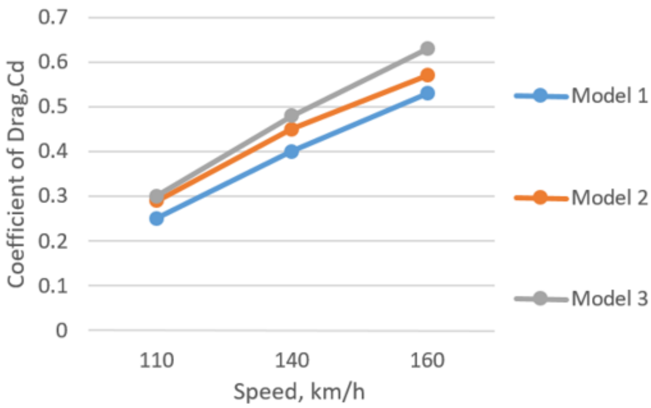

Fig. 7 *Comparison of drag coefficients at various speeds*

The results also show that windshield height has a noticeable influence on the drag coefficient. Model 1, which has the lowest windshield height of 205 mm, produced the lowest drag coefficient at all tested speeds. At 110, 140, and 160 km/h, the drag coefficient values for Model 1 were 0.25, 0.40, and 0.53, respectively. This indicates that the lower windshield configuration provides better aerodynamic efficiency by reducing the effective frontal obstruction to the incoming airflow. This finding is consistent with previous motorcycle aerodynamic studies showing that windshield geometry affects drag and flow behaviour around the motorcycle-rider system [2], [7].

Model 2, with a windshield height of 250 mm, produced slightly higher drag coefficients than Model 1. This suggests that increasing the windshield height causes additional airflow disturbance and increases the resistance acting on the motorcycle. Model 3, which has the highest windshield height of 330 mm, produced the highest drag coefficient at all tested speeds. The drag coefficient values for Model 3 were 0.30, 0.48, and 0.63 at 110, 140, and 160 km/h, respectively. The increase in drag for the taller windshield can be attributed to the larger frontal area and stronger interaction with the approaching airflow, which is consistent with the general aerodynamic relationship between body geometry and drag [5], [6].

Overall, the comparison shows a direct relationship between windshield height and drag coefficient. As the windshield height increases, the drag coefficient also increases. Therefore, from an aerodynamic-efficiency perspective, the lower windshield configuration is preferable because it produces less drag and allows smoother airflow around the motorcycle. However, aerodynamic drag is not the only factor affecting motorcycle performance and rider experience. The pressure distribution on the rider must also be considered because it influences comfort, wind exposure, and fatigue during riding. This trade-off agrees with earlier findings that windshield configuration can improve rider protection even when it affects aerodynamic performance [2], [4].

3.2 Pressure Analysis on the Rider

The static pressure contours for the three windshield configurations are shown in Figs. 8-10. These contours were used to examine how windshield height affects the pressure distribution around the motorcycle and rider. The pressure analysis was conducted at a speed of 140 km/h, where the influence of airflow on the rider becomes more significant. Pressure-contour analysis is useful because it shows how the incoming airflow is redistributed by the windshield and how the rider is exposed to high- and low-pressure regions [8].

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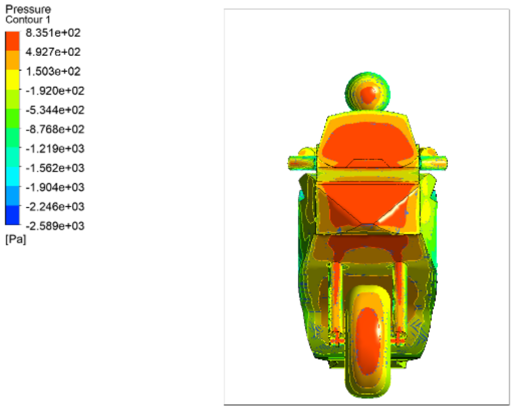

Fig. 8 *Model 1*

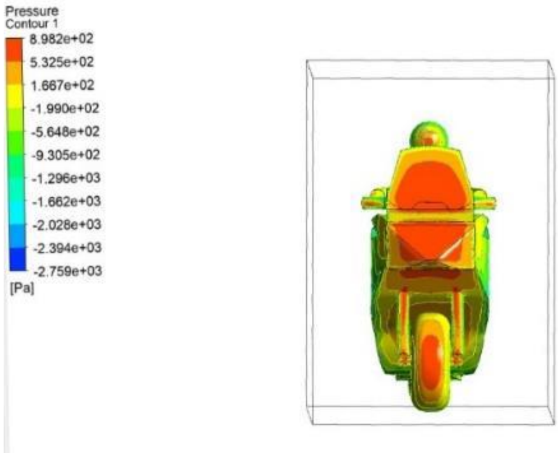

Fig. 9 *Model 2*

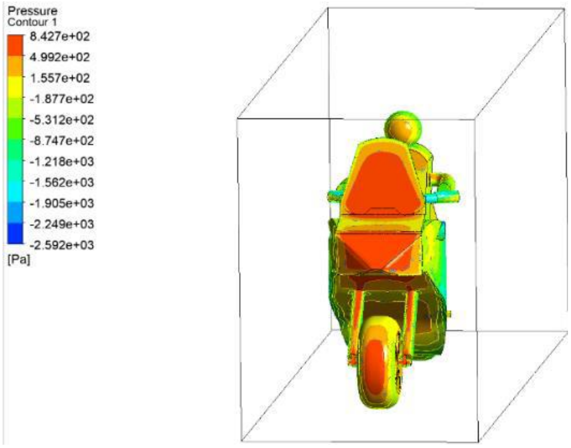

Fig. 10 *Model 3*

For all three models, the highest-pressure concentration was observed at the frontal region of the motorcycle and windshield. This occurs because the incoming airflow first impacts the front surface of the motorcycle, creating a stagnation region where the airflow velocity decreases and static pressure increases [5]. The pressure distribution also shows that the windshield plays an important role in redirecting airflow away from the rider's upper body and head region, which supports previous findings that windshield configuration can influence rider comfort and aerodynamic performance [2], [4].

In Model 1, the lower windshield produced less aerodynamic drag but provided less protection to the rider. As a result, a larger portion of the airflow reached the rider's head and upper body. This condition may increase wind pressure on the rider and contribute to discomfort during high-speed riding. Model 2 showed a moderate pressure distribution compared with Models 1 and 3. The 250 mm windshield provided better shielding than Model 1 while producing less drag than Model 3, suggesting that Model 2 may offer a compromise between aerodynamic efficiency and rider protection. Model 3, which has the tallest windshield, produced the highest drag coefficient but provided the greatest reduction in pressure around the rider's face and upper body. Although this configuration increased aerodynamic resistance, it redirected more airflow away from the rider and reduced direct wind exposure.

The pressure-contour analysis therefore demonstrates a trade-off between aerodynamic drag and rider comfort. A lower windshield reduces drag and improves aerodynamic efficiency, whereas taller windshield increases drag but provides better shielding from wind pressure. These findings indicate that the optimum windshield design should balance drag reduction with rider comfort and protection, depending on the intended riding condition and performance requirement. This interpretation is consistent with studies showing that motorcycle windshield design must consider both aerodynamic performance and rider comfort [2], [4], [7].

4. Conclusion

Motorcycle aerodynamics and rider comfort are closely linked to design variation and performance outcomes. The analysis shows that windshield height is an important factor affecting both aerodynamic efficiency and rider experience. Lower windshields provide better aerodynamic performance by reducing air resistance, whereas taller windshields generate higher drag because of their larger frontal area. However, taller windshields may improve rider comfort by reducing direct pressure on the rider. These findings provide useful information for riders and manufacturers and highlight the need to balance aerodynamic performance with rider safety and comfort. This understanding can support more informed design decisions aimed at improving motorcycle performance and user satisfaction.

The simulations were conducted for three windshield heights (205, 250, and 330 mm) at speeds of 110, 140, and 160 km/h to assess the aerodynamic effects of windshield height. The results show that Model 1, with the lowest windshield height of 205 mm, produced the lowest drag coefficient values of 0.25, 0.40, and 0.53 at 110, 140, and 160 km/h, respectively. In contrast, Model 3, with the highest windshield height of 330 mm, produced the highest drag coefficient values of 0.30, 0.48, and 0.63 at the same speeds.

The results indicate that a taller windshield increases air resistance and, consequently, the drag force acting on the motorcycle. This is supported by the drag force values obtained at 140 km/h, where Models 1, 2, and 3 produced drag forces of 525.99 N, 587.09 N, and 622.82 N, respectively. Model 3, which had the tallest windshield, generated the highest drag force compared with Models 1 and 2. However, the pressure distribution analysis showed that Model 3 reduced pressure on the rider's face. Overall, the aerodynamic analysis successfully demonstrated that windshield height affects both drag performance and rider pressure exposure, and that an effective design must balance aerodynamic efficiency with rider comfort.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contribution

The authors confirm their contributions to the paper as follows: ***study conception and design:*** *Muhammad Arif Marzuki and Mohammad Fahmi Abdul Ghafir;* ***data collection:*** *Muhammad Arif Marzuki;* ***analysis and interpretation of results:*** *Muhammad Arif Marzuki and Mohammad Fahmi Abdul Ghafir;* ***draft manuscript preparation:*** *Muhammad Arif Marzuki. All authors reviewed the results and approved the final version of the manuscript.*

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