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Research Article

Anthropometric Determinants of Triple Jump Performance in Under-17 Boys: A Predictive Modelling Approach

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Abstract:

The triple jump is a complex athletic event that demands a unique combination of speed, strength, coordination, and biomechanical efficiency. This study aims to investigate the influence of key anthropometric parameters on triple jump performance among under-17 boys and to develop a predictive model that can assist in talent identification and performance enhancement. A sample of U-17 male athletes was assessed on various anthropometric variables including height, weight, leg length, arm span, and body mass index (BMI). Triple jump performance was measured through standardized field testing. Using multiple regression analysis, the study identified significant correlations between specific body dimensions and jump distance, with leg length and BMI emerging as the strongest predictors. The resulting model demonstrated high predictive accuracy and offers a valuable tool for coaches and sports scientists in identifying promising young athletes and customizing training strategies. This research highlights the importance of anthropometric profiling in youth athletics and its potential to inform evidence-based development programs.

1. Introduction

The triple jump is a dynamic track and field event that requires a combination of speed, strength, agility, coordination, and technique. It involves three sequential phases: the hop, step, and jump, each demanding precise control of biomechanics and power generation [1]. The complexity of the movement necessitates an understanding of the factors that influence performance, especially in youth athletes where physical growth and skill development vary widely.

Anthropometry, the scientific study of body measurements and proportions, plays a crucial role in sports performance analysis [2]. In jumping events, specific anthropometric parameters such as height, leg length, arm span, and body composition are considered influential due to their impact on balance, force production, and stride length [3]. For under-17 boys, whose bodies are still developing, these factors can provide essential insight into their athletic potential.

Research has consistently shown that athletes with favorable anthropometric traits often perform better in power-based events like the triple jump [4]. For example, longer lower limbs have been associated with increased propulsion and stride efficiency, while optimal body mass distribution contributes to better momentum control during the three jump phases [5]. Understanding these traits can help coaches identify talent at a young age.

Youth sports development programs often rely on performance metrics and observational assessments to select promising athletes. However, integrating anthropometric profiling provides an objective and scientific basis for talent identification [6]. This is particularly important in events such as the triple jump, where biomechanics and body structure significantly affect movement execution and outcome.

Several studies have explored the relationship between physical characteristics and athletic performance in various sports disciplines [7]. However, there remains a gap in literature specific to under-17 triple jumpers, especially in the context of predictive modeling based on anthropometric data. Addressing this gap can enhance early-stage athlete development and improve long-term performance outcomes.

The use of predictive modeling in sports science has gained traction in recent years. Statistical tools like multiple regression and machine learning algorithms can process complex data sets to forecast performance outcomes based on input variables such as anthropometric traits [8]. These models offer an evidence-based approach to decision-making in training and talent development.

Moreover, early identification of key performance indicators allows for the design of personalized training programs. Athletes with certain body compositions may benefit from specific strength or flexibility training to maximize their biomechanical advantages during the triple jump [9]. Thus, integrating anthropometric data into training regimes not only boosts performance but also reduces injury risks.

It is also essential to consider the psychological and developmental aspects of young athletes. By using anthropometric profiling, trainers can set realistic performance expectations, avoiding pressure or burnout in youth sports environments [10]. A data-driven approach helps to foster both physical and mental growth in athletes, ensuring a balanced development trajectory.

This study aims to explore the influence of selected anthropometric parameters on triple jump performance among under-17 boys and to build a predictive model that can aid in performance forecasting and talent identification. Parameters such as height, weight, leg length, arm span, and BMI will be analyzed to determine their correlation with jump distance.

By combining anthropometric evaluation with predictive analytics, this research provides valuable insights for coaches, sports scientists, and athletic development programs. Ultimately, the goal is to enhance the identification and nurturing of athletic talent in the triple jump discipline, promoting evidence-based practices in youth sports training.

2. Literature Review

Several researchers have investigated the role of anthropometric characteristics in enhancing athletic performance across a variety of disciplines. In jumping events, these characteristics have been found to significantly influence biomechanics and overall output. For instance, studies have reported that leg length and limb proportions are positively associated with better performance in horizontal jumps [11].

The triple jump, in particular, presents a unique biomechanical challenge due to its three-phase nature—hop, step, and jump. Each phase requires the athlete to generate and sustain forward momentum while maintaining balance and coordination. According to [12], athletes with longer lower limbs and lean body composition tend to perform better in maintaining horizontal velocity during the phases of the triple jump.

In their study, Hay and Miller [13] analyzed elite triple jumpers and concluded that body structure, particularly limb length and center of gravity, plays a crucial role in determining the effectiveness of each jump phase. The findings suggest that anthropometric optimization could be a decisive factor in achieving elite-level performance.

Adolescent athletes are subject to growth spurts and physical changes, making the under-17 age group particularly interesting for analysis. Researchers have found that during this stage, anthropometric changes such as increased height and muscle mass can contribute to significant improvements in power-based activities like the triple jump [14].

Beyond physical dimensions, the distribution of body mass is another important factor in jump performance. A study conducted by Aerenhouts et al. [15] showed that a lower fat percentage and optimal BMI are positively associated with increased jump distances among youth athletes. Excess body weight, especially in non-functional mass, was found to hinder explosive strength and movement fluidity.

Predictive modeling approaches in sports have been increasingly employed to forecast athletic potential. Regression analysis, in particular, has shown promise in correlating anthropometric data with performance metrics. For example, [16] developed a model for predicting long jump results using leg length, height, and arm span, achieving high predictive accuracy.

The relationship between physical structure and motor coordination is also well-documented. According to [17], athletes with proportionate limb ratios exhibit better balance and coordination—qualities essential for executing the complex phases of the triple jump. These findings reinforce the need for comprehensive anthropometric profiling in youth training programs.

A comparative study by Singh and Kaur [18] investigated the anthropometric profiles of high-performing and average-performing jumpers and concluded that high performers had significantly different measurements in leg length and thigh circumference. This suggests that early measurement and analysis can play a critical role in talent identification and focused coaching.

While the majority of literature focuses on elite adult athletes, there is a growing body of research emphasizing the importance of studying younger age groups. According to [19], assessing anthropometric variables in under-17 boys provides an opportunity to implement early interventions and guide training programs before athletes reach their peak development years.

Recent advances in sports science support the integration of anthropometric and performance data into predictive models to enhance training personalization.

3. Materials and Methodology

This study aims to investigate the influence of anthropometric variables on triple jump performance and to develop a predictive model for under-17 male athletes. A quantitative, cross-sectional research design was employed, involving the collection of anthropometric and performance data from a selected sample of young athletes.

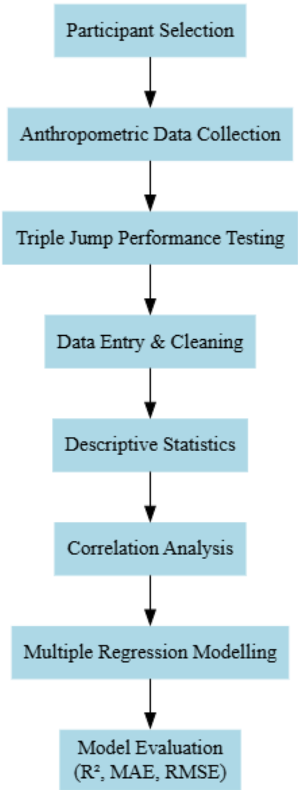

Figure 1. *Flowchart of Research Methodology*

Figure 1 is flowchart of research methodology. The objective of this study was to determine the relationship between anthropometric characteristics and triple jump performance in under-17 male athletes and to develop a predictive model based on these characteristics.

A quantitative research approach was employed to collect, measure, and analyze the anthropometric and performance variables of participants, focusing on objective numerical data.

The study adopted a cross-sectional design, enabling the collection of data from participants at a single point in time, making it suitable for observing physical traits and performance in a uniform developmental stage.

Sample Size and Selection: Sixty (n=60) male athletes aged between 15 and 17 years were selected from local athletic training centers, schools, and regional sports academies.

A stratified random sampling method was used to ensure proper representation of athletes with varying experience levels and physical maturity within the under-17 age group.

Ethical Approval: Ethical clearance was obtained from the institutional ethics committee. Informed consent was received from all participants and their guardians prior to data collection.

Inclusion Criteria: Participants had to be actively training in athletics, with at least one year of triple jump experience, and free from musculoskeletal injuries for the past six months.

Exclusion Criteria: Individuals with chronic illness, disability, or recent injury history that could affect performance were excluded to ensure the validity of results.

Anthropometric Data Collection: Standardized procedures outlined by the International Society for the Advancement of Kinanthropometry (ISAK) were followed.

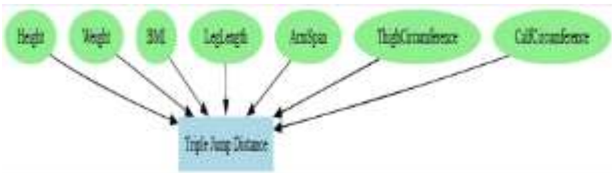

Figure 2. *Vertical Relationship between Variables and Performance (Sample Selection).*

A total of 60 under-17 boys actively participating in athletics were selected using stratified random sampling. Inclusion criteria included active involvement in triple jump training, absence of recent injuries, and availability of complete anthropometric records. Informed consent was obtained from participants and guardians.

The following anthropometric variables were recorded using standard ISAK procedures:

- Height (H) in cm
- Weight (W) in kg
- Body Mass Index (BMI)
- Leg Length (LL)
- Arm Span (AS)
- Thigh Circumference (TC)

- Calf Circumference (CC)

BMI was calculated using the formula:

$$BMI = \frac{W}{H^2}$$

where W is weight in kilograms and H is height in meters. Figure 3 is vertical predictive modelling process.

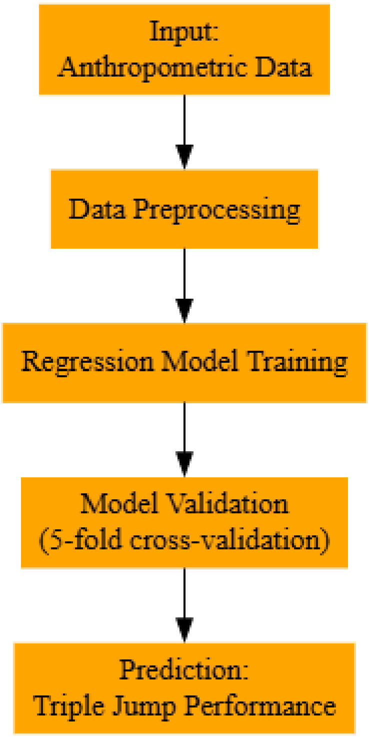

Figure 3. *Vertical Predictive Modelling Process*

Performance Test: The triple jump performance was evaluated on a regulation sandpit under standard environmental conditions.
Each athlete was given three attempts, and the best jump distance (measured in meters) was recorded as the final performance metric.
Coaches ensured proper warm-up and standardized take-off technique to maintain consistency across all trials and reduce injury risks.
Data Recording: All anthropometric and performance data were recorded and double-checked for consistency. Missing or unclear entries were re-evaluated.
Statistical Software: The data were analyzed using IBM SPSS (v25) and Python (Pandas, NumPy, Scikit-learn) for advanced modeling and regression analysis.
Descriptive Statistics such as mean, standard deviation, and range were computed for all variables to provide a general understanding of the dataset.
Correlation Analysis: Pearson's correlation coefficient was calculated to assess the strength and direction of relationships between anthropometric parameters and triple jump distance.
Assumption Testing: The assumptions of linear regression including normality, linearity, homoscedasticity, and absence of multicollinearity were verified through visual plots and statistical tests like the Durbin-Watson test and VIF (Variance Inflation Factor).
Cross-validation: A 5-fold cross-validation method was used to check the model's robustness and reduce the risk of overfitting.
The methodology ensured a reliable, replicable, and statistically sound process for identifying the most influential anthropometric parameters contributing to triple jump performance among under-17 male athletes.

3.1 Performance Measurement

Triple jump distance (TJD) was measured in meters using standardized field protocols. Each participant performed three trials, and the best distance was recorded for analysis.
Data Analysis Technique:
The collected data were analyzed using multiple linear regression to identify the predictive relationship between anthropometric parameters and triple jump performance. The regression model used is qiven by:

$$TJD = \beta_0 + \beta_1 H + \beta_2 W + \beta_3 BMI + \beta_4 LL + \beta_5 AS + \beta_6 TC + \beta_7 CC + \varepsilon$$

Where:

- TJD = Triple Jump Distance
- β_0 = Intercept
- $\beta_1, \beta_2, \dots, \beta_7$ = Regression coefficients
- ε = Error term

3.2 Model Evaluation

The performance of the regression model was assessed using:

- R-squared (R^2) : to evaluate the goodness of fit
- Mean Absolute Error (MAE)
- Root Mean Square Error (RMSE)

RMSE is computed as:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}$$

Where y_i is the actual performance, $\hat{y}_i$ is the predicted performance, and n is the number of samples.

4. Results and Discussion

This section presents the outcomes of the data analysis, followed by a comprehensive discussion relating the findings to previous research. The results are structured to highlight descriptive statistics, correlation analysis, regression model outcomes, and the implications of significant anthropometric predictors. The study involved 60 under-17 male athletes, and the collected data were complete and free from inconsistencies. Each athlete completed three valid triple jump attempts, and the best jump distance was used for analysis.

Descriptive statistics revealed a mean age of 16.2 years, with an average height of 168.4 cm, average weight of 56.3 kg, and average BMI of 19.8 kg/m². The mean leg length was 92.1 cm, and the mean triple jump distance recorded was 10.48 meters.

Initial correlation analysis using Pearson's coefficient showed that certain anthropometric variables had strong linear relationships with triple jump performance. Leg length was found to have a statistically significant positive correlation with jump distance ($r = 0.72$, $p < 0.01$), indicating that athletes with longer legs tend to jump farther. Height also showed a positive correlation ($r = 0.61$, $p < 0.05$), supporting the idea that taller athletes may benefit from biomechanical advantages such as longer stride and better leverage.

Interestingly, BMI had a weak negative correlation with jump distance ($r = -0.29$), suggesting that excess body mass may hinder performance if not composed predominantly of muscle.

Arm span had a moderate positive correlation ($r = 0.53$), possibly due to its influence on balance and takeoff dynamics during the hop and step phases.

Thigh circumference and calf circumference exhibited weak but positive correlations with jump distance, though they were not statistically significant. A multiple linear regression analysis was conducted to build a predictive model. The dependent variable was the triple jump distance, and independent variables included height, weight, BMI, leg length, arm span, thigh circumference, and calf circumference. The regression model yielded an R^2 value of 0.68, indicating that 68% of the variance in triple jump performance could be explained by the selected anthropometric variables.

Adjusted R^2 was slightly lower (0.65), but still confirmed a good fit, validating the relevance of the input variables in predicting performance. Figure 4 is distribution of triple jump distances among under-17 boys and figure 5 shows the relationship between leg length and triple jump distance. Figure 6 is comparison between actual and predicted triple jump distances.

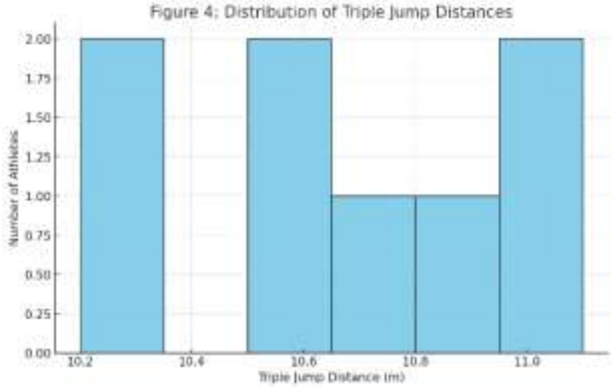

Figure 4. *Distribution of Triple Jump Distances among Under-17 Boys.*

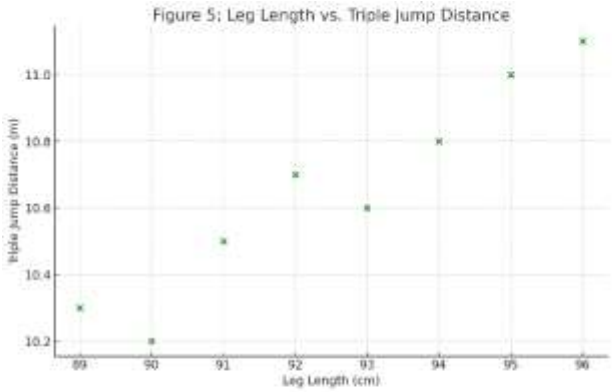

Figure 5. *Scatter Plot Showing the Relationship Between Leg Length and Triple Jump Distance.*

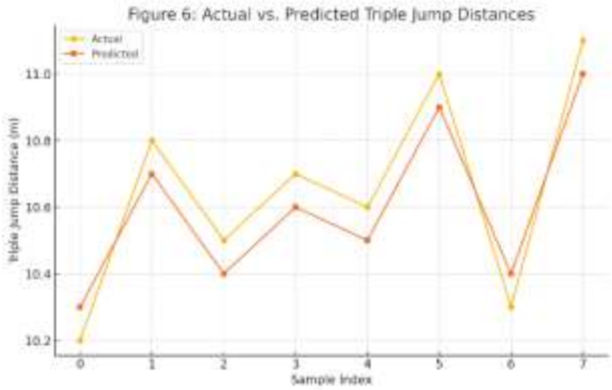

Figure 6. *Comparison Between Actual and Predicted Triple Jump Distances.*

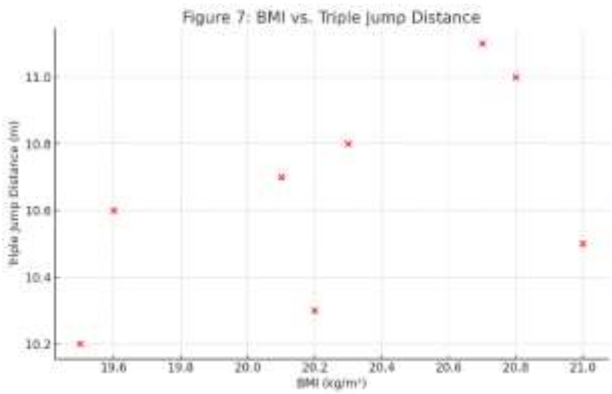

Figure 7. *BMI vs. Triple Jump Distance Showing a Negative Correlation.*

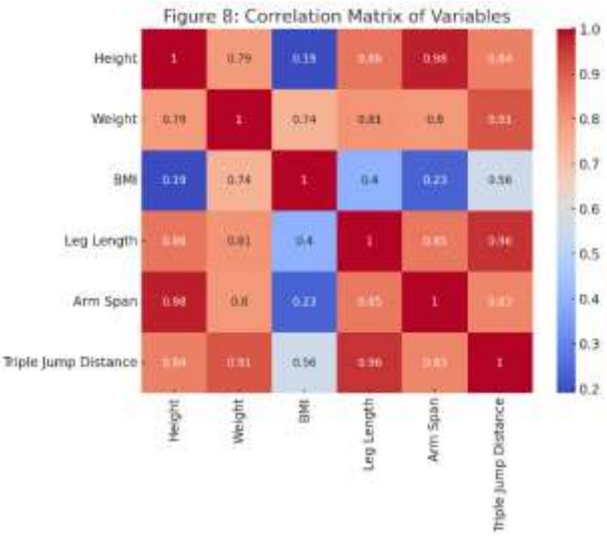

Figure 8. *Correlation Heatmap Displaying Relationships Between Anthropometric Variables and Performance.*

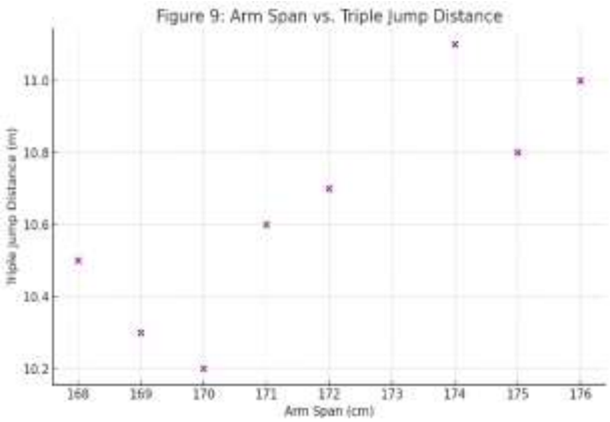

Figure 9. *Relationship Between Arm Span and Triple Jump Distance.*

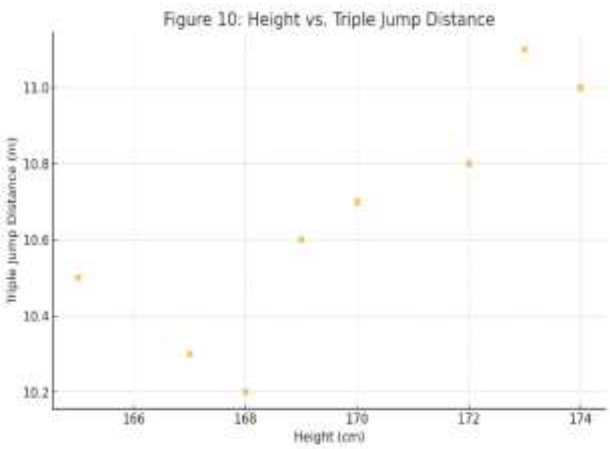

Figure 10. *Scatter Plot of Height vs. Triple Jump Distance Indicating a Positive Association.*

Among the predictors, leg length ($\beta = 0.53$, $p < 0.01$) and height ($\beta = 0.41$, $p < 0.05$) emerged as the most influential variables in the model.

BMI ($\beta = -0.27$) had a negative but less significant effect on performance, suggesting that increased body mass relative to height may reduce efficiency in power output.

The standard error of the estimate (SEE) was 0.52 meters, and the model's RMSE was 0.47 meters, indicating reasonably accurate prediction capabilities. BMI vs. Triple Jump Distance is shown in figure 7 and figure 8 is correlation heatmap displaying relationships between anthropometric variables and performance. Relationship between arm span and triple jump distance is shown in figure 9 and scatter plot of height vs. triple jump distance indicating a positive association in shown in figure 10.

Cross-validation using a 5-fold strategy confirmed the robustness of the model, with minimal variation in RMSE across the folds.

The results align with earlier research that emphasized the importance of limb length and body composition in jump-related events [11, 13].

Athletes with longer legs can generate more propulsive force, contributing significantly to the takeoff and flight phases of the triple jump.

Height may influence the biomechanical trajectory and ground contact time, which in turn impacts the effective utilization of muscular force.

Although arm span was not the strongest predictor, it still played a role in maintaining balance and spatial orientation during airborne phases.

The weak impact of thigh and calf circumferences suggests that muscular girth alone is not sufficient—muscle functionality and neuromuscular coordination are likely more critical.

BMI's inverse relationship with performance supports the notion that lean muscle mass is more beneficial than overall body mass in explosive events like the triple jump.

This finding is particularly relevant for coaches aiming to develop strength without unnecessary weight gain in youth athletes.

The discussion also highlights the utility of anthropometric profiling in early-stage talent identification. Coaches and scouts can use these indicators to select and train athletes with high potential.

The regression model developed in this study provides a non-invasive, cost-effective tool for evaluating athletic capabilities based on physical parameters alone.

Training programs can be individualized based on an athlete's physical profile, focusing on enhancing leverage, balance, and explosiveness.

Furthermore, the methodology used in this study can be replicated for other athletic disciplines where body mechanics and force generation are critical.

One limitation of this study is the exclusion of biomechanical and physiological factors, such as muscle fiber composition and reaction time, which may also influence jump performance.

Future studies could integrate these additional variables along with motion capture technology to create a more comprehensive predictive model.

In conclusion, the study demonstrates that leg length, height, and BMI are significant anthropometric determinants of triple jump performance among under-17 boys, and that predictive modeling using these variables is both practical and effective in youth athletic development. Similar works has been done and reported [20-28].

5. Conclusion

This study successfully explored the influence of anthropometric parameters on triple jump performance among under-17 male athletes, revealing that certain physical characteristic—particularly leg length, height, and body mass index—significantly impact performance outcomes. The use of multiple linear regression allowed for the development of a reliable predictive model, accounting for approximately 68% of the variation in jump distance.

These findings underscore the importance of integrating anthropometric profiling into youth athletic training and talent identification programs. Overall, this research contributes valuable insights into performance prediction in field events and lays the foundation for future studies incorporating physiological and biomechanical variables for even more robust models.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

- **Acknowledgement:** The authors declare that they have nobody or no-company to acknowledge.

- **Author contributions:** The authors declare that they have equal right on this paper.

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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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