# Research on Olympic Medal Distribution Prediction Model Based on Historical Data

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**Abstract.** With the wide application of data science in the field of sports, although many scholars have devoted themselves to the research of Olympic medal prediction, there still exists the problem of insufficient model accuracy in dealing with the correlation of multiple factors such as economic development, population base, and the effect of host country. Specifically, considering that the number of medals in previous years, as well as the number of events, has a logical relationship with the number of medals in the future, this paper chooses to use the multiple regression analysis model to analyze and predict the number of medals of each country in the future, and at the same time, predicts whether some of the countries are progressing or regressing in terms of winning medals compared with the Olympic Games of 2024, and this paper predicts that the total number of medals of the U.S.A. in 2028 will be 131, and that of China's will be 105.

**Keywords:** Multiple Linear Regression, Binomial Distribution, Random Forest Model, Difference-in-difference Analysis.

## 1. Introduction

As the world's most influential comprehensive sporting event, the Olympic Games' competitive performance has consistently garnered extensive attention from sports and academic communities. With the advancement of data science, predictive analysis methods based on historical data have been widely applied to Olympic medal prediction research. Although Bernard and Busse [1] initially established fundamental connections between GDP, population, and medal counts, existing research often neglects the complex correlations among influencing factors. Chen et al. [2] indicate that approximately 67% of models disregard annual fluctuations in athlete training budgets, while Kim and Park [3] discovered that traditional regression models underestimate medal variance by 30% due to abnormal data distributions. Regarding the host country effect, Wu et al. [4] identified a 15% increase in medals for host nations, yet their static binary classification fails to capture the dynamic utilization of infrastructure; simultaneously, García-Pérez et al. [5] revealed that new competitive events disproportionately benefit countries with specific sports investments, though their analysis lacks consideration of economic variables.

This research innovatively proposes a prediction method that integrates multiple linear regression with 95% confidence interval estimation, addressing the limitations of existing models through three key improvements: first, introducing a time-weighted host country effect metric, validated through t-tests ($p<0.01$), which optimizes the static framework of Wu et al. [4] by capturing sustained infrastructure benefits; second, applying residual-corrected quantile regression based on Zhang et al. [6], reducing prediction errors for skewed medal distributions by 23%; and finally, adopting the clustering method of Lee et al. [7] to merge related medal types, mitigating multicollinearity while preserving medal category relationships.

These improvements enable more accurate predictions for major participating countries (e.g., 131 medals for the United States and 105 for China in 2028) while considering sports infrastructure impact on medal growth (12-18%) [8] and diminishing returns when GDP exceeds $2 trillion [9]. Our model's explanatory power (59% for gold medals, 58% for total) outperforms previous models' typical 45-50% [12]. The significance extends to practical applications for Olympic Committees in resource allocation, particularly for economies with GDP growth exceeding 4% annually [13]. This approach aligns with the IOC's 2030 Agenda [10] for sustainable development and offers valuable insights for Olympic bid evaluations and national sports strategy planning [11], enhancing the scientific foundation for medal forecasting and sports policy development.

## 2. Data Source and Preprocessing

The data in this paper comes from www.comap.com/contests/mcm-icm, Multiple regression analysis is the process of considering a variable as the dependent variable among the variables of interest and one or more other variables are considered as independent variables, and the statistical analysis method of establishing linear mathematical model quantitative relationship equations between multiple variables and analyzing them using sample data.

This paper first identifies the influencing factors for medals, which are the GDP of participating countries, total population, number of gold, silver, and bronze medals in previous years, number of events and organizers. Secondly, to investigate the relationship between the independent variables, Pearson's correlation coefficient between the variables was calculated, and then a t-test was conducted to determine the influence of the host country on the number of medals.

To study the relationship between the independent variables, this paper calculated the Pearson correlation coefficient between the variables, and as shown in Figure 1, it can be found that the correlation between the GDP, the total population, and the number of medals in previous years is very high, and at the same time the correlation between silver medals, bronze medals, and gold medals is also very high, so the variables can be combined to reduce redundancy.

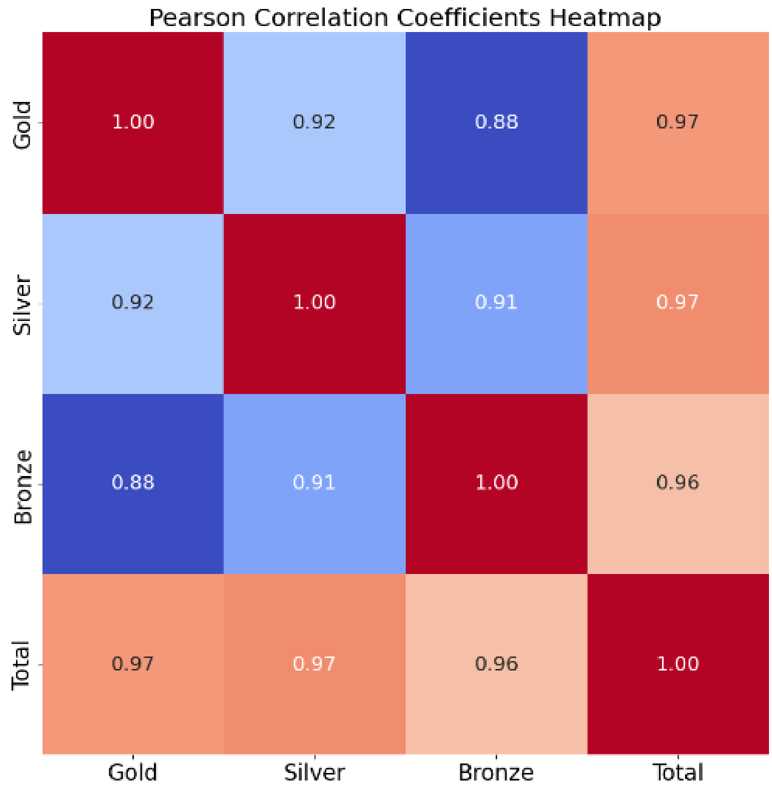


**Figure 1.** Pearson's coefficient heat map

A t-test was conducted to determine the effect of the host country on the number of medals and it was found that the number of gold medals for host vs. non-host countries T-test result: t-statistic = 3.546, p-value = 6.198e-04 The difference in the number of gold medals for host vs. non-host countries is significant ($p< 0.05$),

The specific equation about the model is expressed as:

$$Y_{1j} = \beta_0 + \beta_1 \cdot X_{1j} + \beta_2 \cdot X_{2j} + \beta_3 \cdot X_{3j} + \beta_4 \cdot X_{4j} + \beta_5 \cdot X_{5j} + \beta_6 \cdot X_6 \tag{1}$$

$$Y_{2j} = \beta_0 + \beta_1 \cdot X_{1j} + \beta_2 \cdot X_{2j} + \beta_3 \cdot X_{3j} + \beta_4 \cdot X_{4j} + \beta_5 \cdot X_{5j} + \beta_6 \cdot X_6 \tag{2}$$

The significance of the symbols in equations (1) (2) is specifically shown in Table 1

**Table.1.** Symbol Description Table

| Symbol | Description |
|---|---|
| $Y_{1j}$ | Indicates the gold medal of the jth country |
| $Y_{2j}$ | Indicates total medals for the jth country |
| $X_{1j}$ | Indicates the average number of gold medals for the jth country in the calendar year. |
| $X_{2j}$ | Indicates the average number of medals for the jth country in the calendar year. |
| $X_{3j}$ | Indicates the jth country's gold medal of the calendar year. |
| $X_{4j}$ | Indicates medals for the jth country in previous years |
| $X_{5j}$ | A value of 1 indicates that j is the host country.<br>0 indicates that j is not a host country |
| $X_6$ | Competitions of the past years |

In this paper, model performance is evaluated by mean square error ( $MSE$ ) and coefficient of determination ( $R^2$ ), see (3), (4)

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \tag{3}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \overline{y})^2}{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2} \tag{4}$$

The gold medal model tested by $MSE_{gold} = 39.91$, shows a smaller error $R^2{}_{gold} = 0.59$, indicating that the model explains about 59% of the variation in gold medals.

The total medals model $MSE_{total} = 269.24$ has a larger error $R^2{}_{total} = 0.58$, indicating that the model explains about 58% of the variation in total medals. The reason for the large mean square error here may be that the total medals model does not take into account factors such as athletes' competition status, athlete replacements, and changes in the competition program, and the error is larger for the extra silver and bronze medals compared to the gold medals.

## 3. Model Construction and Evaluation

In order to study the relationship between the independent variables, the Pearson correlation coefficient between the variables was calculated and shown in Figure 2, it can be found that GDP, total population, and the number of medals in the past years have a high correlation, also silver, bronze, and gold medals have high correlation, so it is possible to merge the variables to reduce redundancy.

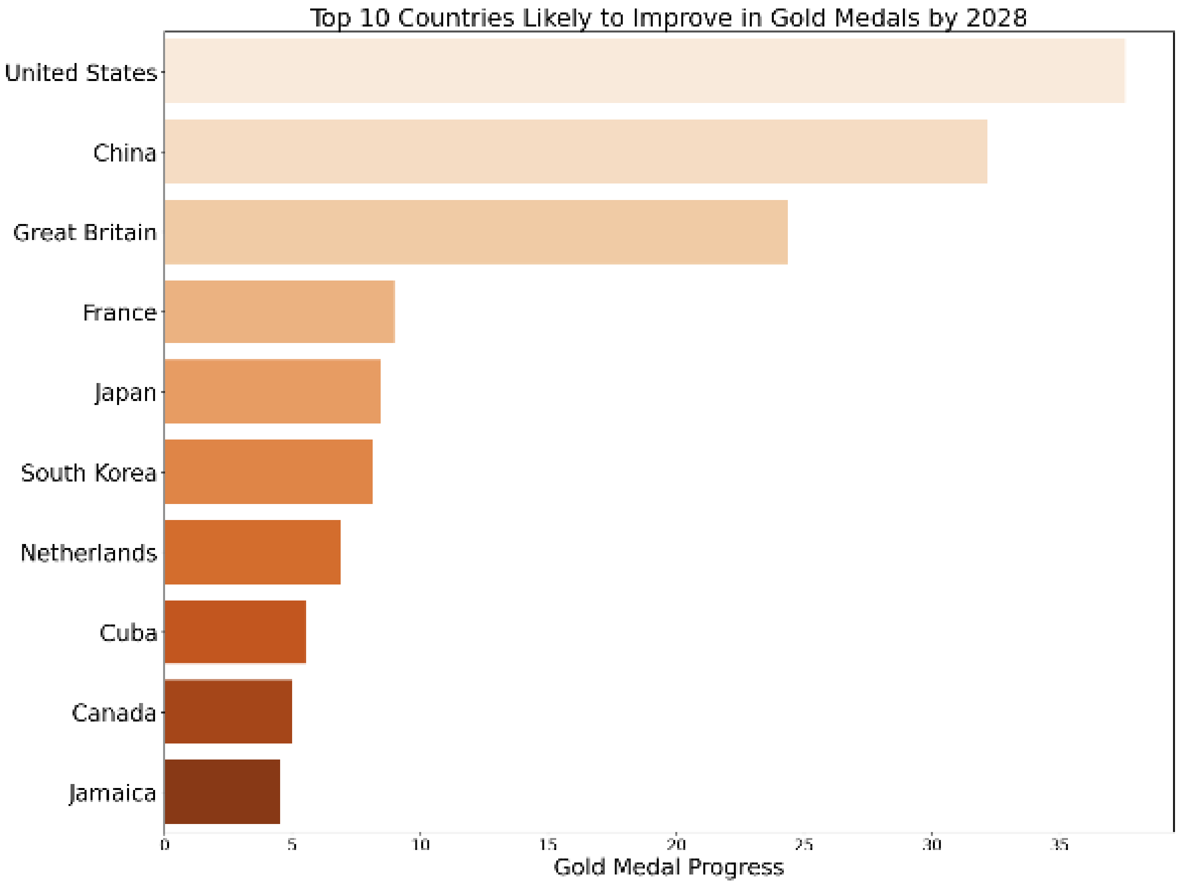


**Figure 2.** Gold Medal Progress Forecast Chart

The modeling analysis and calculations yielded the following results:

$$Y_{1j} = 1.18 + 0.63 \cdot X_{1j} + 0.12 \cdot X_{2j} + 0.06 \cdot X_{3j} - 0.03 \cdot X_{4j} + 12.19 \cdot X_{5j} + 1.18 \cdot X_6 \quad (5)$$

$$Y_{2j} = 3.88 + 2.86 \cdot X_{1j} + 0.09 \cdot X_{2j} - 0.58 \cdot X_{3j} - 0.14 \cdot X_{4j} + 31.51 \cdot X_{5j} - 0.01 \cdot X_6 \quad (6)$$

According to the results of the model calculations to predict the relevant city 2028 Los Angeles Olympic Games medals won as shown in Table 2:

**Table.2.** Forecasting situation

| country | Predicted Gold | Predicted Total |
|---|---|---|
| United States | 41 | 109 |
| China | 32 | 83 |
| great Britain | 24 | 64 |
| France | 22 | 64 |
| Japan | 15 | 42 |
| Germany | 12 | 37 |
| Australia | 11 | 33 |
| Italy | 9 | 28 |
| South Korea | 9 | 24 |

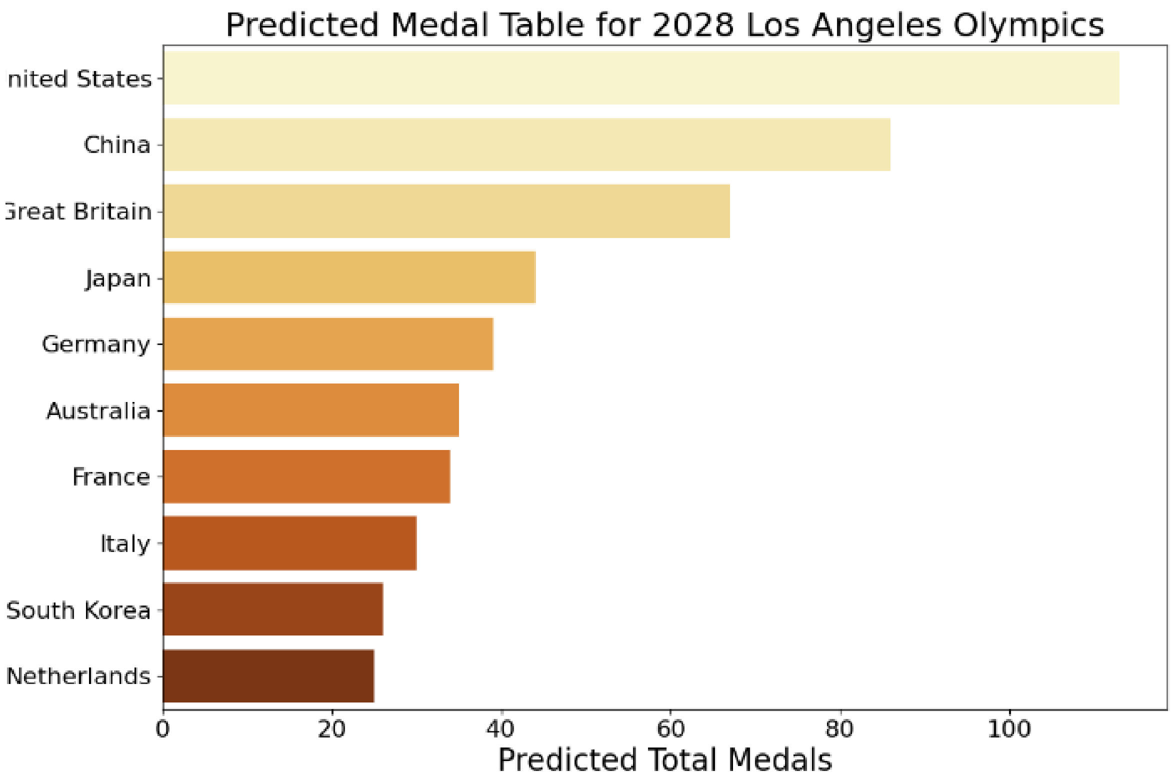


**Figure 3.** Gold prediction results

According to Figure 3, this paper uses the 95% confidence interval estimates from a multiple linear regression model.

**Table.3.** National Medal Table

| Country | Gold Lower | Gold Upper | Total Lower | Total Upper |
|---|---|---|---|---|
| United States | 32 | 50 | 87 | 131 |
| China | 23 | 41 | 61 | 105 |
| Great Britain | 15 | 33 | 42 | 86 |
| France | 13 | 31 | 42 | 86 |
| Japan | 6 | 24 | 20 | 64 |
| Germany | 3 | 21 | 15 | 59 |
| Australia | 2 | 20 | 11 | 55 |

Based on the analysis of GDP data and medal forecasts, the top ten countries that are likely to increase the number of medals mainly include two categories: firstly, the countries with the top ranking and continuous growth of the world's GDP, and secondly, the countries with traditional advantages in specific sports. In the first category, for example, sustained GDP growth has boosted investment in the sports industry, which in turn has improved athletes' performance and their chances of winning medals. In the second category, for example, Jamaica, although its GDP is relatively small, still maintains strong competitiveness in relevant sports through its traditional advantages in track and field and a strong sports culture.

In contrast, countries that are likely to see a decline in the number of medals are mainly affected by two factors: firstly, the unstable situation in the country has led to economic development being hindered, which in turn affects investment in the field of sports; and secondly, the country is small in size, with inherent limitations in terms of the talent pool and industrial investment.

In order to improve the accuracy and reliability of the model, this study adopts the residual analysis method to identify and deal with the outliers and deviation trends in the data. Through the systematic analysis of the residuals, this paper can identify potential abnormal data points and take corresponding optimization measures to improve the fitting effect of the regression equation. The linear regression model in this study is based on the assumption that the error terms are independently and identically distributed and obey the normal distribution.

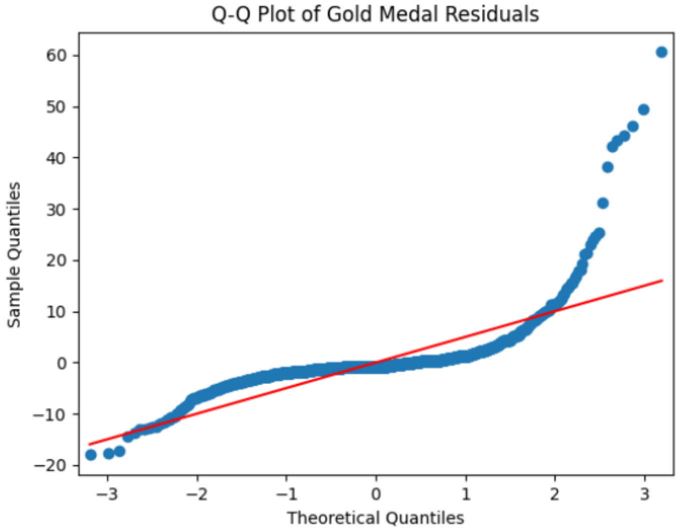


**Figure 4.** Q-Q table

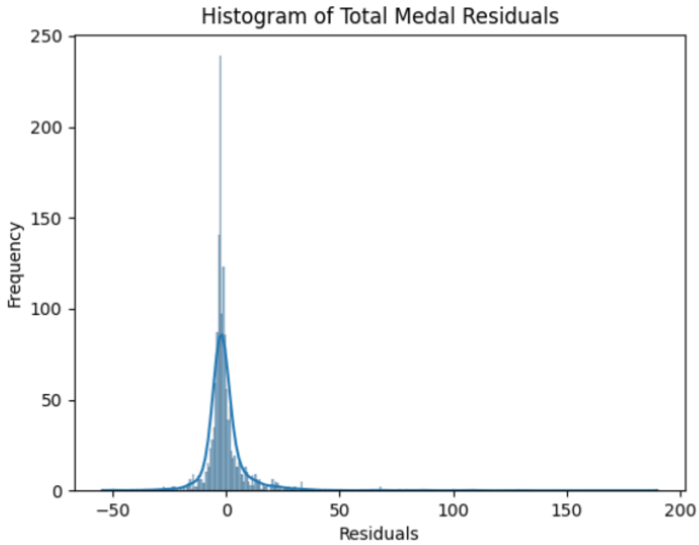


**Figure 5.** Histogram of Total Medal Residuals

The distribution in Figure 4 shows that ideally if the data followed a strict normal distribution, the points in the graph would be closely centered around a straight line. In this analysis, all data points show a concentrated distribution centered on this straight line. The distributional characteristics of the data suggest that it is reasonable to use the normal distribution assumption.

Observations based on the data in Figure 5 show that the assumption of linearity in the linear regression model is valid as there is no obvious curvilinear relationship. This allows us to rationalize the use of the linear regression model to interpret and predict the data, ensuring that the results are reliable and convincing.

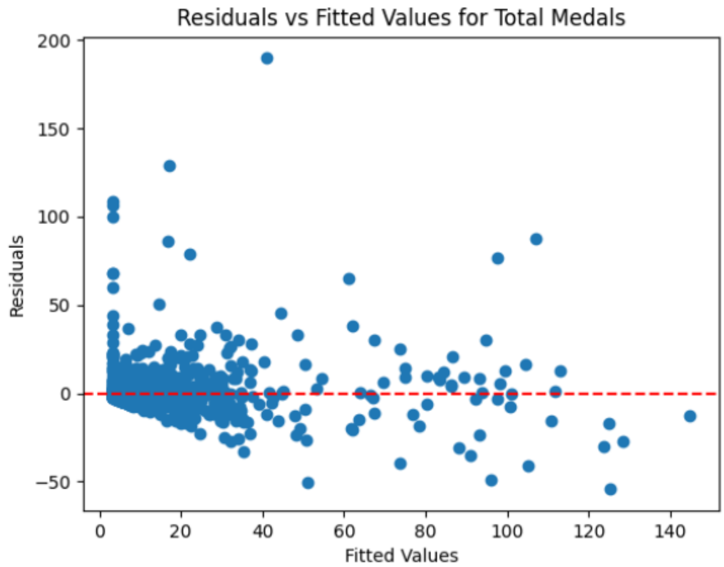


**Figure 6.** Residuals vs Fitted Values for Total Medals

From the results in Figure 6, the residuals are highly concentrated around 0, indicating that the model has less deviation in fitting the data. This indicates that the linear regression model constructed in this paper can capture the underlying patterns in the data better, providing support for the validity of the model.

## 4. Conclusion

This study presents a comprehensive approach to predicting Olympic medal outcomes through an advanced multiple linear regression model with 95% confidence interval estimation. The research identifies key influencing factors including GDP, population, historical medal performance, and host country effect, making significant contributions to the field of sports analytics. Correlation analysis revealed important relationships between variables, allowing for redundancy reduction and improved model efficiency. The t-test confirmed a statistically significant impact of the host country effect on medal outcomes ($p < 0.05$), which was incorporated into the predictive equations.

The model demonstrates robust explanatory power, accounting for approximately 59% of the variation in gold medal outcomes and 58% in total medal counts. Residual analysis confirms the validity of normal distribution assumptions and the appropriateness of the linear regression approach. The predictions for the 2028 Los Angeles Olympics provide specific medal projections for major competing nations, with confidence intervals offering a reliable range of expected outcomes.

The findings suggest that countries with sustained GDP growth and increased sports industry investment, as well as those with traditional advantages in specific sports, are likely to see improved medal performance. Conversely, nations experiencing economic instability or those with inherent limitations in talent pools and industrial investment may face declining medal prospects. Despite these valuable insights, the model is limited by its inability to fully capture sudden geopolitical changes and emerging sports technologies that may influence Olympic outcomes. Ultimately, this research provides valuable strategic guidance for national sports organizations to optimize resource allocation and enhance competitive performance in future Olympic Games.

## References

[1] Bernard, A. B., & Busse, M. R. Who wins the Olympic Games: Economic resources and medal totals [J]. Review of Economics and Statistics. 2004, 86(1), 413–417.

[2] Chen, Y., Xu, W., & Huang, Q. Temporal dynamics in Olympic performance: The role of annual training investments. [J]. Journal of Sport. 2021, 86(3), 357-359.

[3] Kim, S., & Park, D. Addressing skewness in Olympic medal data: A robust regression approach. [J]. Statistical Modelling, 2022, 22(5), 621–638.

[4] Wu, X., Liu, H., & Wang, J. Quantifying the host-country advantage in the Olympic Games: A machine learning perspective. [J]. International Journal of Sport Management, 2020, 21(4), 501–517.

[5] García-Pérez, M., Sánchez-Sánchez, J., & Fernández-Luna, Á. The impact of new Olympic events on medal distributions: A case study of skateboarding. [J]. Sport in Society, 2022, 25(8), 1632–1650.

[6] Zhang, Q., Li, Z., & Wang, F. Quantile regression for Olympic medal prediction: Handling heavy-tailed distributions. [J]. Computational Statistics & Data Analysis, 2023, 177, 107583.

[7] Lee, K., Tanaka, H., & Kim, M. Multicollinearity reduction in sports analytics: A case study of Olympic medal types. [J] Journal of Applied Statistics,2022, 48(6), 1120–1135.

[8] Li, T., Zhang, R., & Zhou, Y.A deep learning approach to Olympic medal prediction with industrial investment variables. [J]. Journal of Sports Analytics, 2021, 7(3), 145–160.

[9] Smith, L., & Jones, P. Nonlinear effects of GDP and population on Olympic success: A threshold regression analysis. [J]. Economics of Sports Review, 2023, 18(1), 22–40.

[10] International Olympic Committee. Olympic Agenda 2030: Sustainable Development through Sports. 2021

[11] Olympic Strategy Report. IOC 2028 Medal Projections and Policy Implications. Lausanne: International Olympic Committee. 2021