Mathematics and Statistics 10(6): 1141-1158, 2022 http://www.hrpub.org
DOI: 10.13189/ms.2022.100601

Mathematical Model for 100- and 200-meter Olympic Games Running Championship Time Records

Agung Prabowo[1,*], Ngadiman[2]

[1]Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Jenderal Soedirman, Purwokerto, Indonesia
[2]Department of Physical Education, Faculty of Health Sciences, Universitas Jenderal Soedirman, Purwokerto, Indonesia

Received June 29, 2022; Revised September 21, 2022; Accepted October 11, 2022

Cite This Paper in the Following Citation Styles

(a): *[1] Agung Prabowo, Ngadiman , "Mathematical Model for 100- and 200-meter Olympic Games Running Championship Time Records," Mathematics and Statistics Vol. 10, No. 6, pp. 1141 - 1158, 2022. DOI: 10.13189/ms.2022.100601.*

(b): *Agung Prabowo, Ngadiman (2022). Mathematical Model for 100- and 200-meter Olympic Games Running Championship Time Records. Mathematics and Statistics, 10(6), 1141 - 1158. DOI: 10.13189/ms.2022.100601.*

Abstract The 100 and 200- meter running championships for both males and females were first held in 1948 at London Olympic Games 1948. Some time records made by the running champions have been continuously improved. Thus, running championship is not only intended to win the gold medals but also to make new world records. The secondary data were in the form of running championships' time records used to formulate the mathematical models and determine the minimum time limits (fastest). This research used the time-record data of 100 and 200- meter running championships for both males and females winning the gold medals from the Olympic Games held in 1948 to 2020. The mathematical Model for 100 and 200- meter running championships was more appropriately formulated using a logarithmic regression equation. Meanwhile, the time records for running championships of 100 meters for females as well as those of 200 meters for both males and females used a simple linear regression. The world record for running 100 meters for males still belongs to Usain Bolt (9.63 seconds). By using an assumption that the time records are normally distributed, those time records can be broken/improved into 9.53 seconds. Moreover, if the analysis is made using a box-plot diagram, the fastest time can be 9.42 seconds. A similar conclusion was also obtained for the world records of running 100 meters for females and 200 meters for males and females mentioning that the recently achieved time records still can be broken/improved in the future.

Keywords Mathematical Model, Olympic Games, Simple Linear Regression, Logarithmic Regression, Fastest Time

1. Introduction

The mathematical model is the illustration of a system using mathematical concepts and mathematical language. Currently, mathematical models are not only used in natural science, but also in every part of human life. The mathematical model can be extensively defined as the formulation or expression of a physical process's important variables.

Any achievement, including sports achievement, is always interesting to humans. In athletics championships, the main performance is not only achieving gold medals, but also to improving the record or making a new record. This research examined the time records made by the running champions to reach the finishing line in athletics championships. This research used the data of 100 and 200 meters running championships for both males and females in the Olympic Games in the last 75 years from 1948 to 2020, especially the time records of running champions who won gold medals. As commonly known, Olympic Games have been held from 1896 once every 4 years, with an absence in 1940 and 1944.

The variable observed in the research was the time records made by running champions who won gold medals in Olympic Games for 100 and 200- meters running championships for both males and females. This research did not model 400 meters running championships for either for males or females. The 100 and 200- meter running championships were chosen since these championships were more prestigious than the 400- meter ones. This research was carried out aiming at answering the following questions:

1. How is the mathematical model for the time records of 100 and 200- meter running championships both for males and females in the Olympic Games in 1948 - 2020?
2. Is there any minimum (fastest) time limit for male and female athletes in 100 and 200- meter running championships?

This research is important since the research results can be referenced or time limit in the selection of and sending feasible athletes to running championships. The research's other urgency is that the research findings can serve as a recommendation to generate a different mathematical model.

2. Materials and Methods

2.1. Research Variables

The research variable was the time records made by champions winning gold medals in the 100 and 200- meter running championships for both males and females in the Olympic Games from 1948 – 2020. The time records were placed as the dependent variable, while the independent variable was the years of Olympic Games events.

This research is re-parameterized by altering the years of Olympic Games events into number order from 1, 2, …, 19, while in their research, Mishra and Kaur [7] maintain the years of Olympic Games events as the independent variable.

2.2. Data Analysis and Technique

The data analysis in this research used simple linear regression and logarithmic regression. Regression selection was based on a data pattern plot. The regression equation obtained served as the mathematical model for the case studied [2]. The regression model was used by assuming that the years of Olympic Games events affected the time records the running athletes made. This was the case since in each event all athletes attempted to improve or break the world records. Thus, the data analysis chosen was a regression, instead of time series.

To choose the best mathematical model, the biggest determination coefficient value (R^2) was used [2]. Meanwhile, an analysis with normal distribution and a box-plot diagram were used to determine the minimum (fastest) time limits for male and female athletes in 100 and 200- meter running championships.

2.3. Data Collection

This research used secondary data collected from the internet [4-5]. The Olympic Games which were first held in Athens from 1896 through 1936 only held a running championship for males and there were two occasions the Olympic Games were absent in 1940 and 1944. Therefore, this research did not use the whole Olympic Games data, but from Olympic Games 1948 to 2020. The data in this period covered 100 and 200- meter running championships both for males and females.

The research limitations are first, the time record model was not made for 400 meters running championship for males and females and, second, the model was not made for silver and bronze medals for all events.

3. Results and Discussion

3.1. Research Variables

Research in the field of sports has used many mathematical models, including optimum control, logarithmic functions, logistic regression and linear regression. Woodside [11] built a mathematical model to maximize the distance traveled for a known length of time. The model obtained is solved by mathematical theories in the field of optimum control.

Furthermore, Vandewalle [10] uses a mathematical model built by Kennelly in 1906 and a logarithmic model made by Peronnet-Thibault in 1989 to model the relationship between time and speed. The use of simple and multiple logistic regressions is also found in sports research. Lapresa et al. [6] used logistic regression in their research on the sport of football.

The use of linear regression in predicting running time has been widely used in various studies. How and Zhang [3] used linear regression to determine the travel time in the men's 110-meter hurdles at the 31st Olympics for the three fastest runners. The results obtained are the achievement of champions is 12.91, runner up is 13.09 and the third-place is 13.11.

Arnold and Godbey [1] provide an illustration of the use of simple linear regression in a basketball game. Students were given an explanation about explanatory variables, 2-squared, and the estimation of regression parameters. Simple examples are given to make it easier to understand the material and become familiar. In the end, students were asked to repeat the same procedure for several different data. Likewise, Mishra and Kaur [7] used a simple linear regression model in their research. Agung *et al*. [13] and Jetsada *et al*. [12] offer a new method for estimating linear regression parameters when classical methods for estimating regression parameters cannot be used. Agung *et al*. [13] used the Simple Averaging (SA) method based on the mean value in estimating the regression parameters. While Jetsada *et al.* [13]. Estimation of regression parameters using the Improved Simple Averaging (ISA) method based on the median value.

Similar research has been conducted by Mishra and

Kaur [7] using the data from Olympic Games from 1948 to 2008 in the 200- meter running championships for both males and females. In the article, mathematical models of time records for running a championship of 200 meters for both males and females winning three medals, namely gold, silver and bronze, were made. The models generated were in the form of the simple linear regression equation.

Since the results presented by Mishra and Kaur [7] show similarity in the mathematical models for the three types of medals, this article would only specifically discuss gold medal and add data for the last three Olympic Games, and additional time records for 100 meters running championship for both male and female. Besides, the statistical techniques used in this research were more complete.

Table 1. Time records of gold-medals championship winning 100 meters running championship for both male and female

Year	Place	Male	Time (Seconds)	Female	Time (Seconds)
1896	Athena	Thomas Burke	12.0	-	-
1900	Paris	Frank Jarvis	11.0	-	-
1904	St. Louis	Archie Hahn	11.0	-	-
1908	London	Reggie Walke	10.8	-	-
1912	Stockholm	Ralph Craig	10.8	-	-
1920	Antwerp	Charles Paddock	10.8	-	-
1924	Paris	Harold Abrahams	10.6	-	-
1928	Amsterdam	Percy Williams	10.8	Elizabeth Robinson	12.2
1932	Los Angeles	Eddie Tolan	10.3	Stanislawa Walasiewicz	11.9
1936	Berlin	Jesse Owens	10.3	Helen Stephens	11.5
1948	London	Harrison Dillard	10.3	Fanny Blankers-Koen	11.9
1952	Helsinki	Lindy Remigino	10.4	Marjorie Jackson	11.5
1956	Melbourne	Bobby Morrow	10.5	Betty Cuthbert	11.5
1960	Rome	Armin Hary	10.2	Wilma Rudolph	11.0
1964	Tokyo	Bob Hayes	10.0	Wyomia Tyus	11.4
1968	Mexico City	Jim Hines	9.95	Wyomia Tyus	11.00
1972	Munich	Valeriy Borzov	10.14	Renate Stecher	11.07
1976	Montreal	Hasley Crawford	10.06	Annegret Richter-Irrgang	11.08
1980	Moscow	Allan Wells	10.25	Lyudmila Kondratyeva	11.06
1984	Los Angeles	Carl Lewis	9.99	Evelyn Ashford	10.97
1988	Seoul	Carl Lewis	9.92	Florence Griffith Joyner	10.62
1992	Barcelona	Linford Christie	9.96	Gail Evers	10.82
1996	Atlanta	Donovan Bailey	9.84	Gail Devers	10.94
2000	Sydney	Maurice Greene	9.87	Not awarded	-
2004	Athena	Justin Gatlin	9.85	Yuliya Nestsiarenka	10.93
2008	Beijing	Usain Bolt	9.69	Shelly-Anne Fraser-Price	10.78
2012	London	Usain Bolt	9.63	Shelly-Anne Fraser-Price	10.75
2016	Rio d Janeiro	Usain Bolt	9.81	Elaine Thompson	10.71
2020	Tokyo	Lamont Marcell Jacobs	9.80	Elaine Thompson-Herah	10.61

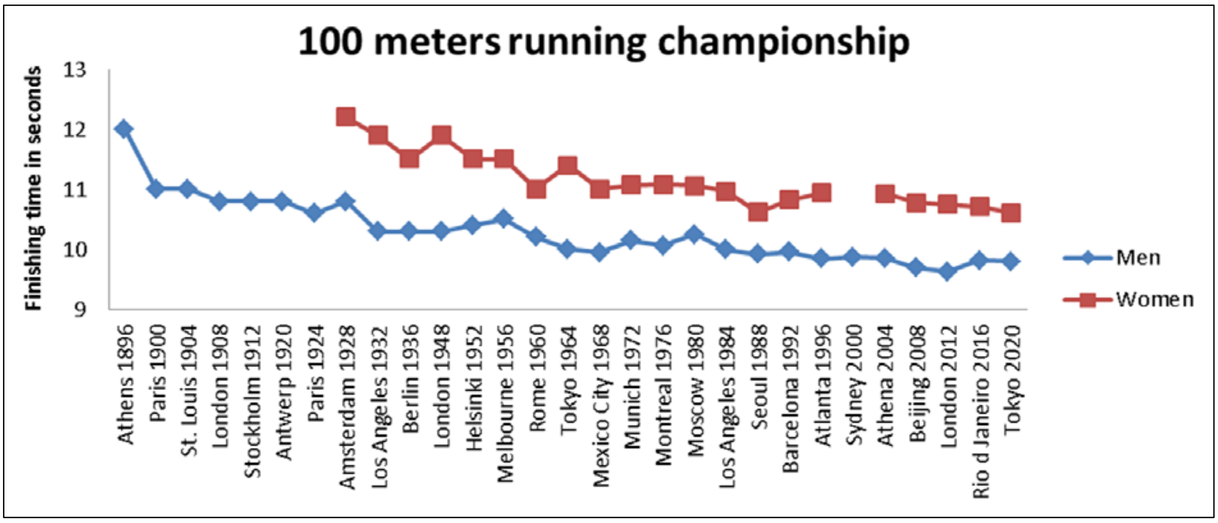


Figure 1. Graphics of time records of gold-medal champions winning the Olympic Games of 1896 – 2020 in 100 meters running championships for both male and female

3.2. Description of Data for 100 Meters Running Championships

The data used in this research are presented in Table 1 and Table 3. The champion of 100 meters running championship for males in the Olympic Games 1988 was actually Ben Johnson (Canada). However, Johnson was declared positively consuming drugs two days later. Carl Lewis was promoted to the first champion, making him the first athlete to maintain the title. Johnson's World Time Records obtained in 1981 and 1988 were also annulled, making Lewis's time record of 9.92 seconds the new World Record. Still in Olympic Games 1988, Florence Griffith Joyner's time record was deemed to be with the "help of the wind". Consequently, the official World Record for 100 meters running championship for females was Joyner's fastest legal time record without wind's help of 10.62 seconds.

In Olympic Games 2000, the champion of 100 meters event for females was initially Marion Jones (AS). However, Jones acknowledged consuming performance-enhancing drugs and her medal was annulled. As the runner-up, Ekaterini Thanou (Greece) was once involved in a doping scandal before Olympic Games 2004, thus she could not be promoted to the first champion. On the contrary, the third and fourth running champions were respectively promoted to second and third. Thus, in Olympic Games 2000 there was no female champion in 100 meters running championship.

Starting from Olympic Games in 1968, it was possible to correctly measure up to approximate one- hundredth of a second. Running for 100 meters in 10 seconds, for example, will result in an average speed of 10m/s. Thus, the athlete travels 10 x 0.01 m = 0.1 m = 10 cm in one- hundredth of a second. This illustration explains the necessity of time measurement up to one hundredth of a second or two digits after a comma.

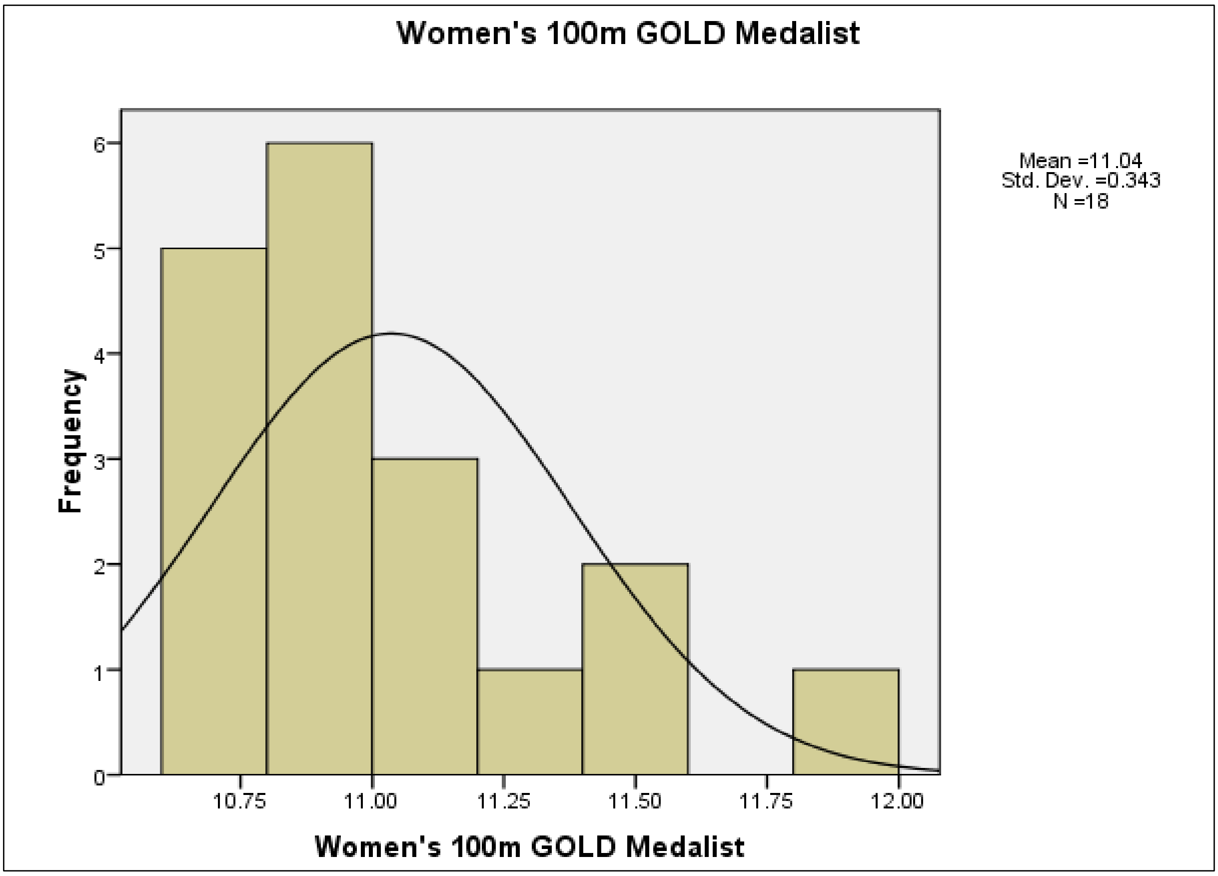
The measurement of time record up to two digits after comma does not only show a more accurate recording, but also the decreasing difference in time. This was the case since with the more evenly distributed capability of champion 1 making a time record of 9.87 seconds with champion 2 making a time record of 9.89 seconds, their time records must be carefully recorded and distinguished. The third reason is related to the fastest time records made in previous championships with quite a slight improvement of time record. For example, assuming the current best record is 9.63 seconds, a better record may be made at 9.61 seconds. Therefore, the use of two digits after a comma is a must. If one digit after a comma is still in use, the 9.63 seconds will be recorded as equal to 9.61 seconds which is 9.6. This means there is no improved record.

Figure 1 shows graphics of time records in Table 1 for 100- meter running championships for males and females from the first Olympic Games in Athens in 1896 to the Olympic Games in Tokyo in 2020. Table 2 is the output of descriptive statistics for time records of 100- meter running championships for males and females, the result of data processing using SPSS. Figure 2 is the histogram for time records of 100- meter running championships for males and females.

According to Figure 1, there is a decline in the time of completion of 100 meters running championship both for males and females. From Table 2, there are mean, standard deviation, kurtosis, skewness, range, minimum, maximum, and 25th, 50th and 75th percentile values. The values would be used for further analysis in the section Description of Data for the 200 Meters Running Championship. From Figure 2, we can expect that the time records for winning gold medals in 100- meter running championships for males and females were from a normally distributed population. For certainty, a normality test would be conducted in the section Description of Data for 100 Meters Running Championship.

Table 2. The output of descriptive statistics for time records of gold-medal champions winning the Olympic Games of 1948 – 2020 in 100- meter running championships for both males and females

		Women's 100m GOLD Medalist	Men's 100m GOLD Medalist
N		18	19
Valid Missing		2	1
Mean		11.0356	10.0084
Median		10.9850	9.9600
Mode		11.00[a]	9.63[a]
Std. Deviation		.34261	.23677
Variance		.117	.056
Skewness		1.085	.521
Std. Error of Skewness		.536	.524
Kurtosis		.989	-.355
Std. Error of Kurtosis		1.038	1.014
Range		1.29	.87
Minimum		10.61	9.63
Maximum		11.90	10.50
Percentiles	25	10.7725	9.8400
	50	10.9850	9.9600
	75	11.1600	10.2000
a. Multiple modes exist. The smallest value is shown			



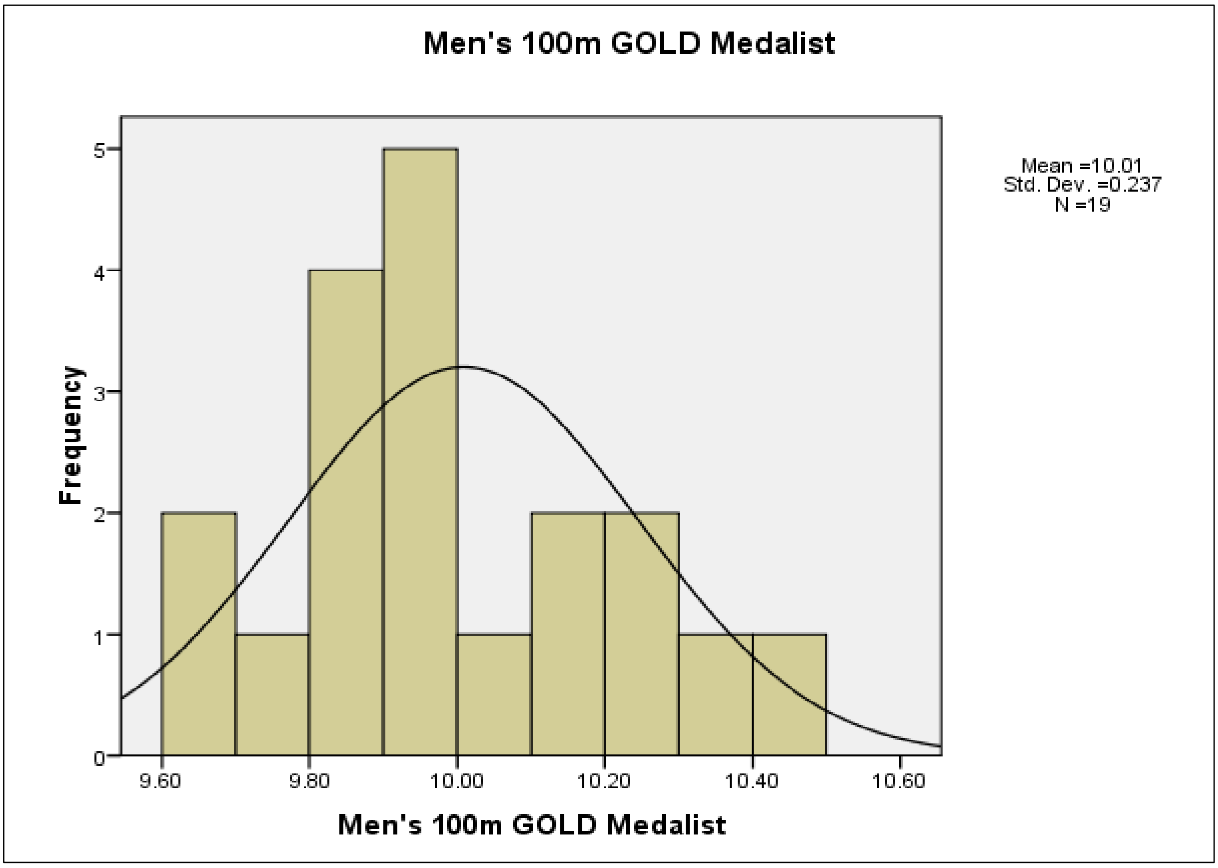


Figure 2. Histogram for time records of gold-medal champions winning the Olympic Games of 1948 – 2020 in 100 meters running championships for both male and female

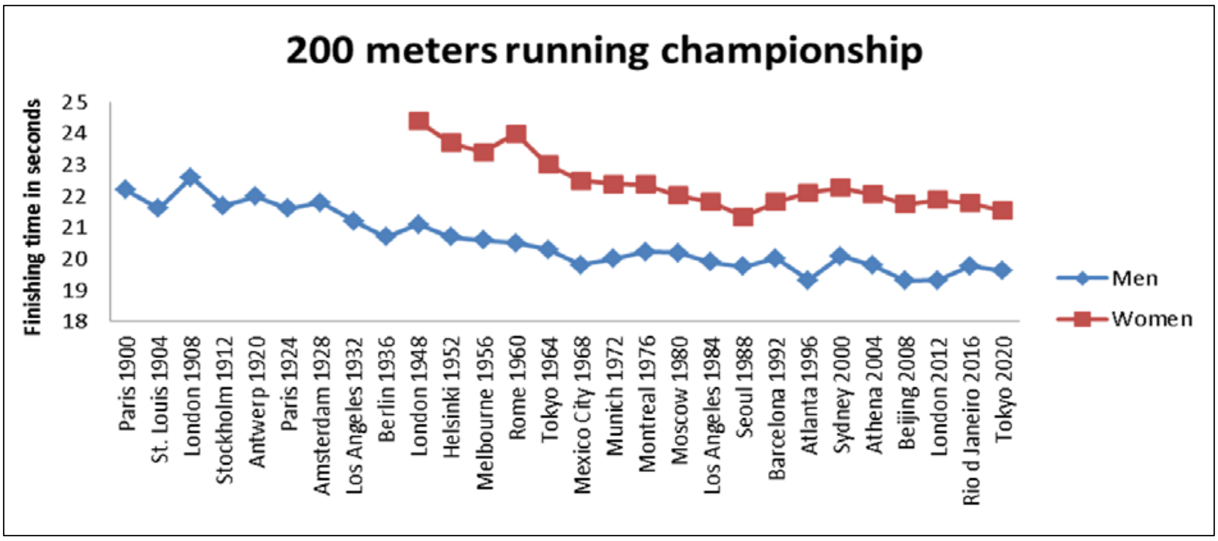


Figure 3. Graphics of time records of gold-medal champions winning the Olympic Games of 1900 – 2020 in 200 meters running championships for both male and female

3.3. Description of Data for 200 Meters Running Championships

Table 3 shows the time records for winning gold medals in Olympic Games for 200 meters running championships for both males and females. In Table 3, numbers in grey show different data from the data recorded and used by Mishra and Kaur [7].

Figure 3 shows graphics of time records for 200- meter running championships for both males and females from the second Olympic Games in Paris in 1900 to the Olympic Games in Tokyo in 2020. Table 4 is the output of descriptive statistics for Time Records of 200 meters championships for males and females, as the result of data processing using SPSS. Figure 6 is the histogram for the time record of 200 meters running championships for both males and females.

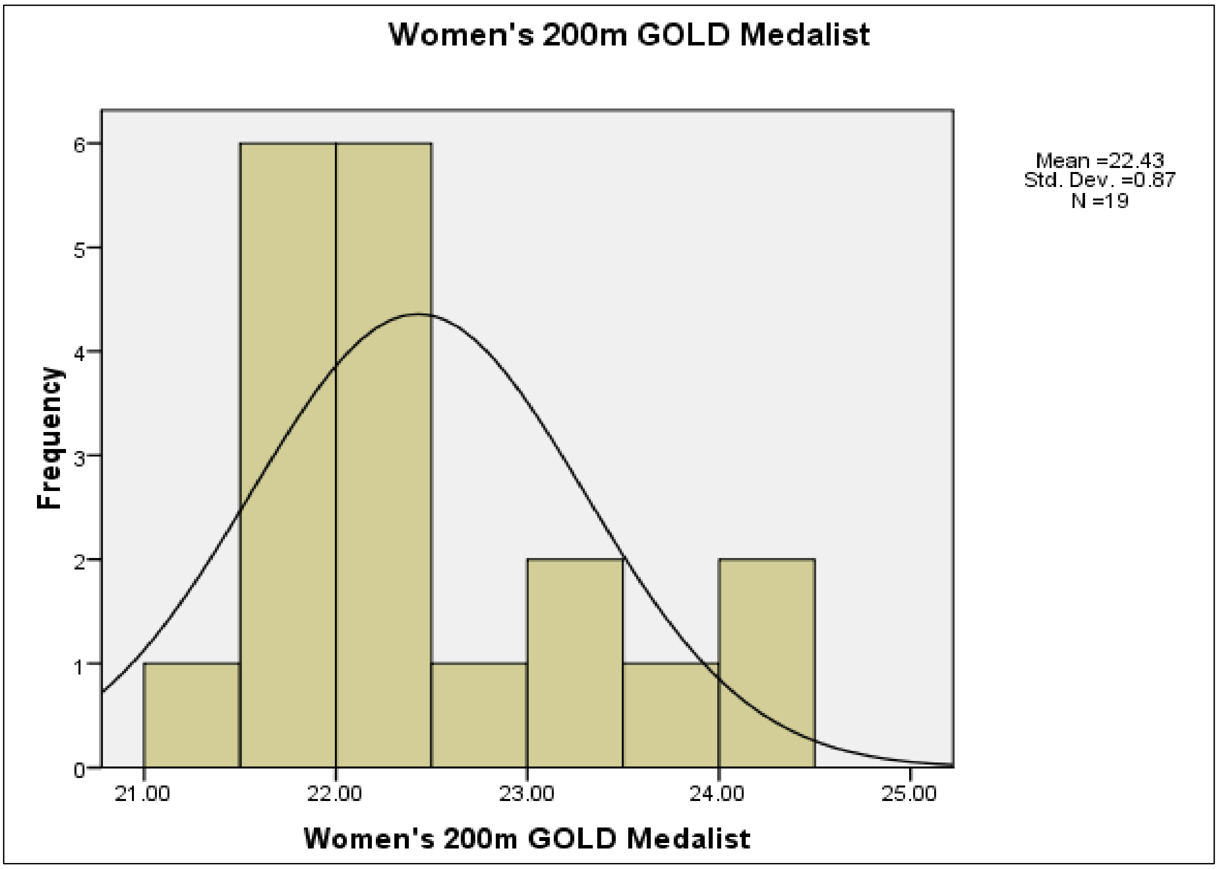
Just like Figure 1, in Figure 3 there is a decline in the time of completion of 200- meter running championships, both for males and females. Expectedly, a mathematical equation will be obtained in the form of similar linear regression or logarithmic regression for both championships. From Table 4 and Figure 4, similar information was obtained to information from Table 2 and Figure 2.

Table 3. Time records of gold-medals championship winning 200 meters running championship for both male and female

Year	Male	Time (Seconds)	Female	Time (Seconds)
1900	Walter Tewksbury	22.2	Walter Tewksbury	-
1904	Archie Hahn	21.6	Archie Hahn	-
1908	Robert Kerr	22.6	Robert Kerr	-
1912	Ralph Craig	21.7	Ralph Craig	-
1920	Allen Woodring	22.0	Allen Woodring	-
1924	Jackson Scholz	21.6	Jackson Scholz	-
1928	Percy Williams	21.8	Percy Williams	-
1932	Eddie Tolan	21.2	Eddie Tolan	-
1936	Jesse Owens	20.7	Jesse Owens	-
1948	Mel Patton	21.1	Fanny Blankers-Koen	24.4
1952	Andy Stanfield	20.7	Marjorie Jackson	23.7
1956	Bobby Morrow	20.6	Betty Cuthbert	23.4
1960	Livio Berruti	20.5	Wilma Rudolph	24.0
1964	Henry Carr	20.3	Edith McGuire	23.0
1968	Tommie Smith	19.80	Irena Kirszenstein	22.50
1972	Valeriy Borzov	20.00	Renate Stecher	22.40
1976	Donald Quarrie	20.23	Bärbel Eckert-Wöckel	22.37
1980	Pietro Mennea	20.19	Bärbel Eckert-Wöckel	22.03
1984	Carl Lewis	19.90	Valerie Brisco	21.81
1988	Joe Deloach	19.75	Florence Griffith Joyner	21.34
1992	Michael Marsh	20.01	Gwen Torrence	21.81
1996	Michael Johnson	19.32	Marie- José Pérec	22.12
2000	Kostas Kenteris	20.09	Pauline Davis	22.27
2004	Shawn Crawford	19.79	Veronica Campbell-Brown	22.06
2008	Usain Bolt	19.30	Veronica Campbell-Brown	21.74
2012	Usain Bolt	19.32	Allyson Felix	21.88
2016	Usain Bolt	19.78	Elaine Thompson	21.78
2020	Andre de Grasse	19.62	Elaine Thompson- Herah	21.53

Table 4. The output of descriptive statistics for time records of gold-medal champions winning the Olympic Games of 1948 – 2020 in 200 meters running championships for both male and female

		Women's 200m GOLD Medalist	Men's 200m GOLD Medalist
N		19	19
Valid Missing		1	1
Mean		22.4284	20.0158
Median		22.1200	20.0000
Mode		21.81	19.32
Std. Deviation		.86988	.48629
Variance		.757	.236
Skewness		1.067	.426
Std. Error of Skewness		.524	.524
Kurtosis		.183	-.033
Std. Error of Kurtosis		1.014	1.014
Range		3.06	1.80
Minimum		21.34	19.30
Maximum		24.40	21.10
Percentiles	25	21.8100	19.7500
	50	22.1200	20.0000
	75	23.0000	20.3000
a. Multiple modes exist. The smallest value is shown			



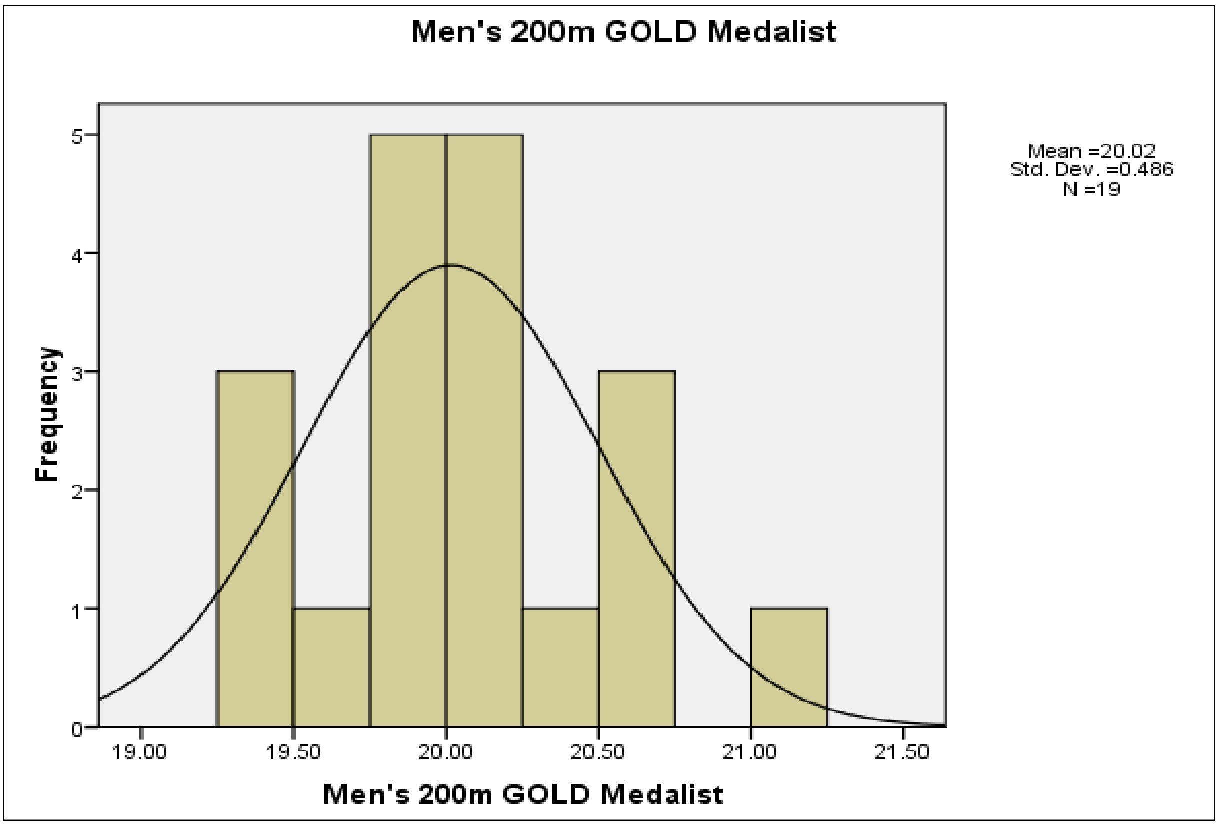
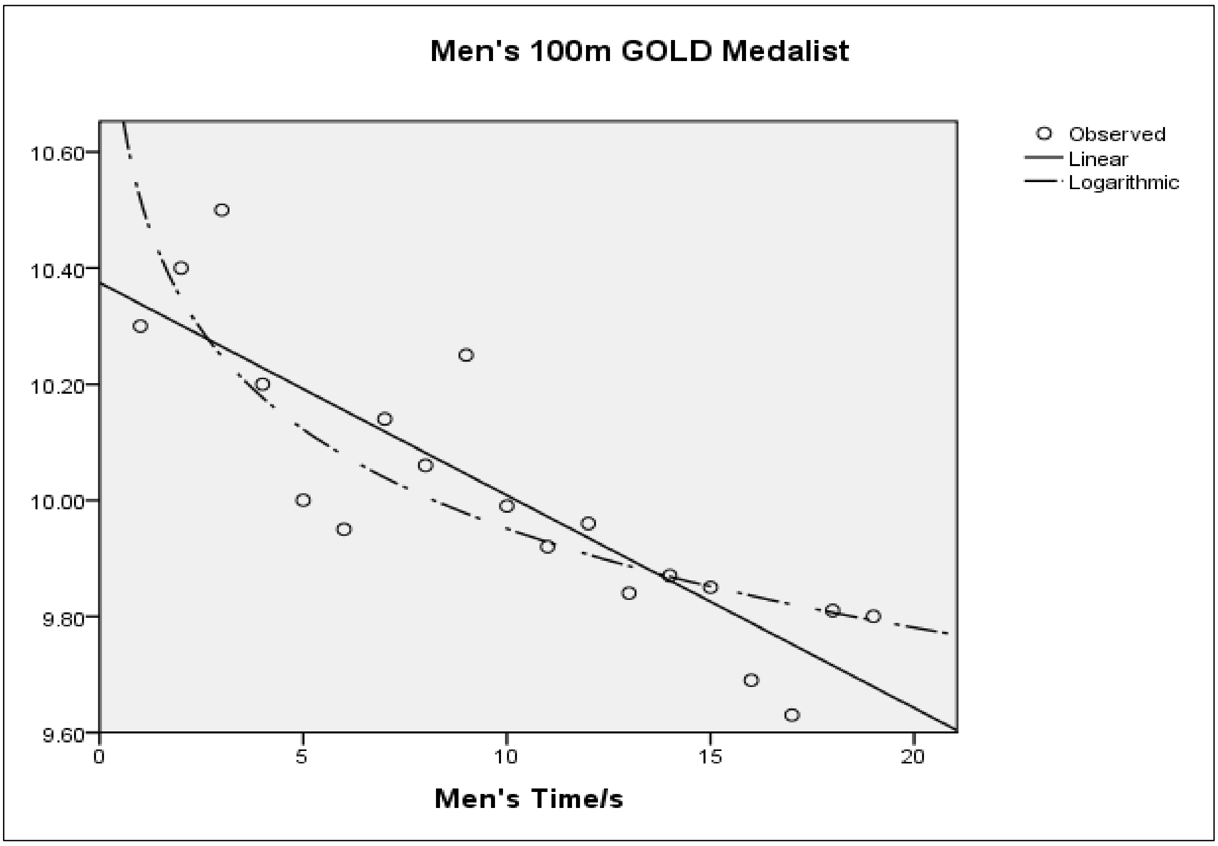
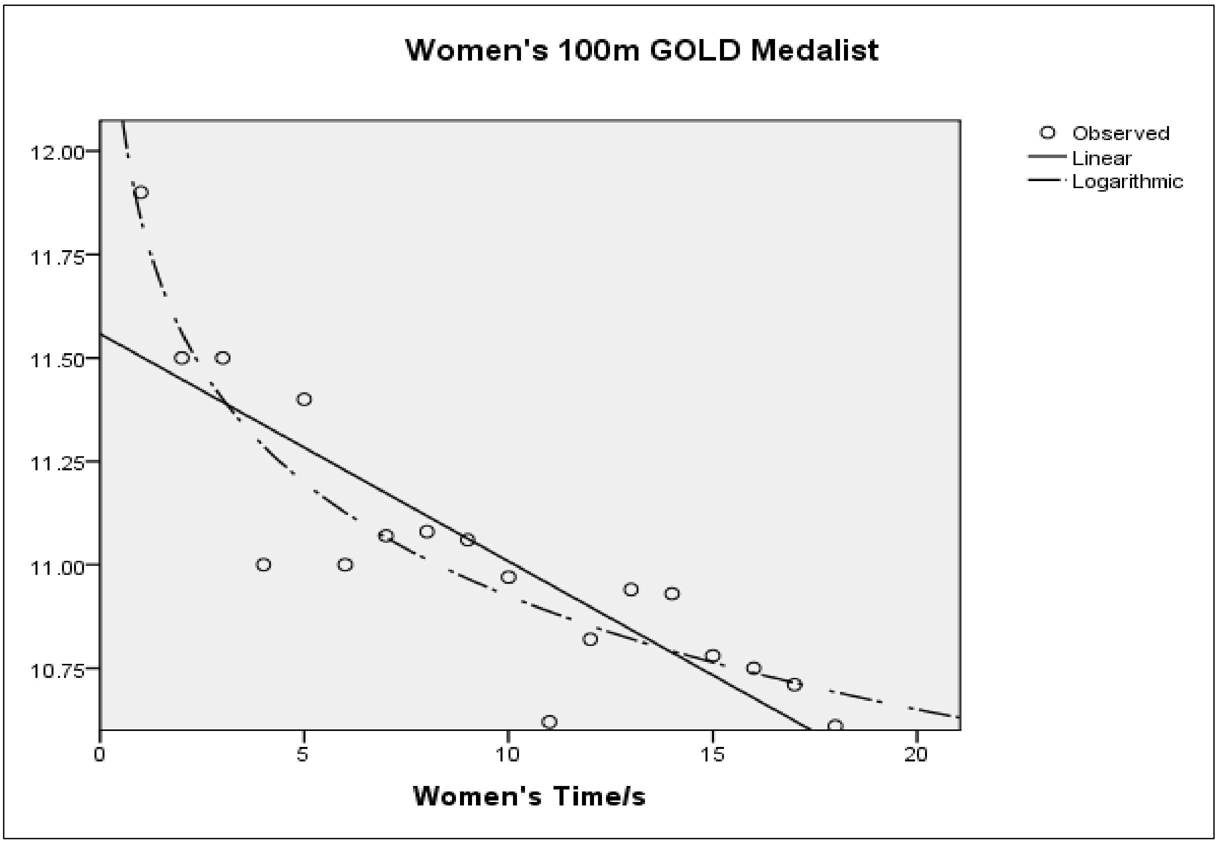


Figure 4. Histogram for time records of gold-medal champions winning the Olympic Games of 1948 – 2020 in 200 meters running championships for both male and female




Women's 100m GOLD Medalist
12.00
11.75
11.50
11.25
11.00
10.75
0
5
10
15
20
Women's Time/s
Observed
Linear
Logarithmic


Men's 200m GOLD Medalist
21.50
21.00
20.50
20.00
19.50
19.00
0
5
10
15
20
Men's Time/s
Observed
Linear
Logarithmic

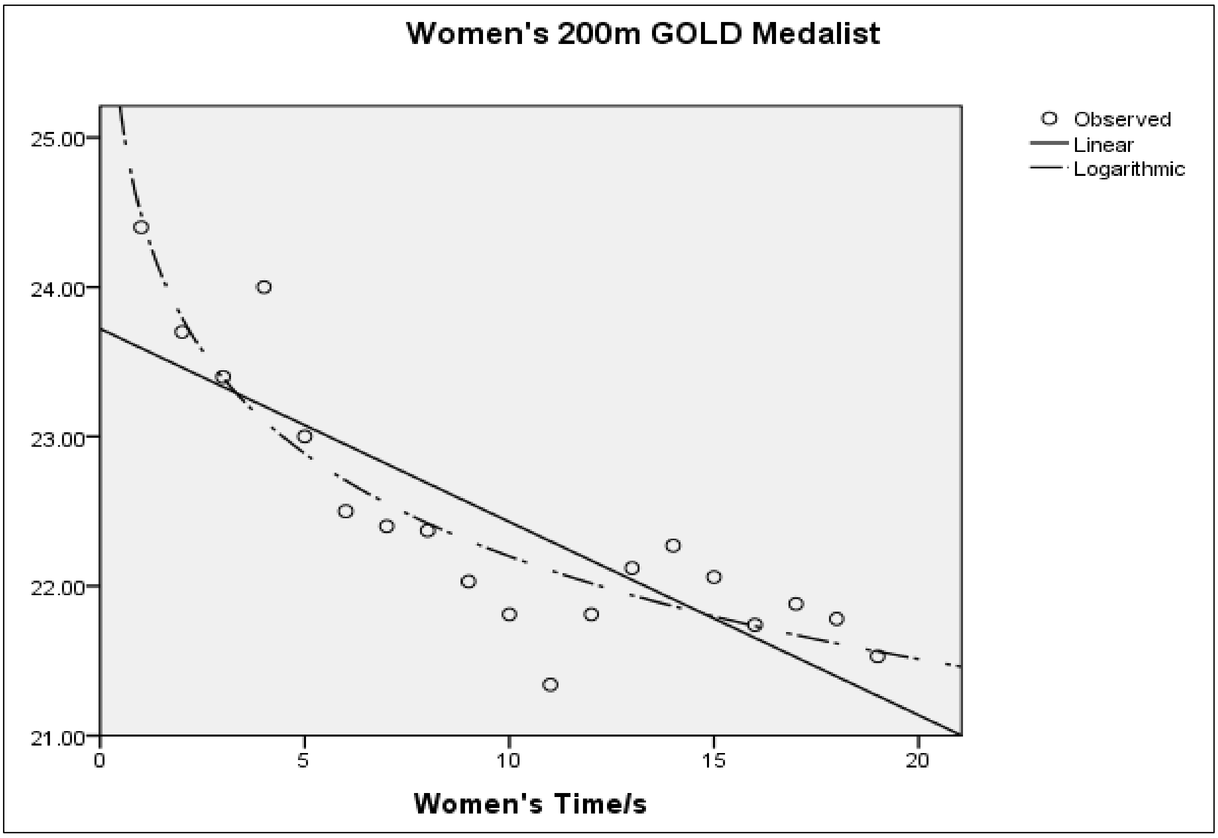


Figure 5. Plot for time records of 100 and 200 meters running championships for both male and female

3.4. Mathematical Models

The research's independent variable was the year of Olympic Games events as stated in sequences 1, 2, …, 19 consecutively for 1948, 1952, …., 2020. The dependent variable was the time record of running championships. If independent variable *x* states sequence, the years are stated as

$$1948 + 4(x - 1)\ ;\ \text{where } x = 1, 2, 3, \ldots. \quad (1)$$

The plot between the year and time of 100 and 200 meters running championships for both males and females is given in Figure 5.

Based on the plot data generated (Figure 5), mathematical models were obtained, which were simple linear regression and logarithmic regression models. The models obtained were presented in (2) to (9).

1. Linear and Logarithmic Regression Models of Champions Winning Gold Medals in 100 Meters Running Championships for Male

$$y = -0.037x + 10.375 \quad (2)$$

$$R2 = 0.757, R = 0.870$$

$$y = 10.518 - 0.246 \ln x \quad (3)$$

$$R2 = 0.705, R = 0.840$$

2. Linear and Logarithmic Regression Models of Champions Winning Gold Medals in 100 Meters Running Championships for Female

$$y = -0.055x + 11.558 \quad (4)$$

$$R2 = 0.735, R = 0.857$$

$$y = 11.835 - 0.396 \ln x \quad (5)$$

$$R2 = 0.857, R = 0.926$$

3. Linear and Logarithmic Regression Models of Champions Winning Gold Medals in 200 Meters Running Championships for Male

$$y = -0.072x + 20.738 \quad (6)$$

$$R2 = 0.698, R = 0.835$$

$$y = 21.121 - 0.534 \ln x \quad (7)$$

$$R2 = 0.786, R = 0.886$$

4. Linear and Logarithmic Regression Models of Champions Winning Gold Medals in 200 Meters Running Championships for Female

$$y = -0.129x + 23.721 \quad (8)$$

$$R2 = 0.699, R = 0.836$$

$$y = 24.481 - 0.991 \ln x \quad (9)$$

$$R2 = 0.847, R = 0.92$$

By choosing a bigger R^2 value, logarithmic regression models (5), (7) and (9) were chosen for 100 meters running championships for females, and 200 meters for both males and females. Meanwhile, for 100- meter running championship for males, linear regression model (2) was chosen.

The R^2 determination coefficient states that the independent variable, that is the years of Olympic Games events, affects the dependent variable, that is time record, as much as the R^2 value. The remainder ($1 - R^2$), meanwhile, is determined by other variables beyond this study. A determination coefficient was used to measure the compatibility of a model with data, of how a good regression line obtained is close to an actual data value. The regression model is good if the R^2 value ranges from 0.600 – 0.799 and very good if the R^2 value is higher or equal to 0.800 [9].

Meanwhile, the closeness level (relationship strength) between the independent variable and dependent variable is measured using a correlation coefficient. The correlation coefficient is the square root of the determination coefficient. If the correlation coefficient value ranges between 0.600 – 0.799 the relationship is strong, and very strong if correlation coefficient value is higher than or equal to 0.800 [8].

The equations obtained can be used to predict the time needed by athletes to travel 100 and 200 meters in running championships for both males and females. Besides extrapolative prediction, it can also be used for interpolation. Table 3 shows (interpolative) prediction from 1948 – 2020 and original data as well as (extrapolative) prediction from 2024 – 2032 for time records of 100 and 200 meters running championships for both males and females, consecutively calculated using (2), (5), (7), and (9). From 1968, the time records were measured up to two digits after the comma.

In Table 5, predictions for time records of Olympic Games 2024 – 2032 or the next 3 Olympic Game events were made. The regression model is still appropriate for short-term prediction and it needs to be improved in case new data are available. Therefore, predictions can only be made until the next 3 Olympic Games events. Based on the results of prediction in Table 5, time improvement which can be created in a very strict range is 0.02 – 0.06 seconds.

Table 5. Prediction for time records of 100 and 200 meters running championships for both males and females (in seconds)

Year	100 Meters for Male		100 Meters for Female		200 Meters for Male		200 Meters for Female	
	Data	Prediction	Data	Prediction	Data	Prediction	Data	Prediction
1948	10.3	10.3	11.9	11.8	21.1	21.1	24.4	24.5
1952	10.4	10.3	11.5	11.6	20.7	20.8	23.7	23.8
1956	10.5	10.3	11.5	11.4	20.6	20.5	23.4	23.4
1960	10.2	10.2	11.0	11.2	20.5	20.4	24.0	23.1
1964	10.0	10.2	11.4	11.2	20.3	20.3	23.0	22.9
1968	9.95	10.15	11.00	11.13	19.80	20.16	22.50	22.71
1972	10.14	10.12	11.07	11.06	20.00	20.08	22.40	22.55
1976	10.06	10.08	11.08	11.01	20.23	20.01	22.37	22.42
1980	10.25	10.04	11.06	10.97	20.19	19.95	22.03	22.30
1984	9.99	10.01	10.97	10.92	19.90	19.89	21.81	22.20
1988	9.92	9.97	10.62	10.89	19.75	19.84	21.34	22.11
1992	9.96	9.93	10.82	10.85	20.01	19.79	21.81	22.02
1996	9.84	9.89	10.94	10.82	19.32	19.75	22.12	21.94
2000	9.87	9.86	-	10.79	20.09	19.71	22.27	21.87
2004	9.85	9.82	10.93	10.76	19.79	19.68	22.06	21.80
2008	9.69	9.78	10.78	10.74	19.30	19.64	21.74	21.73
2012	9.63	9.75	10.75	10.71	19.32	19.61	21.88	21.67
2016	9.81	9.71	10.71	10.69	19.78	19.58	21.78	21.62
2020	9.80	9.67	10.61	10.67	19.62	19.55	21.53	21.56
2024	-	9.64	-	10.65	-	19.52	-	21.51
2028	-	9.60	-	10.63	-	19.50	-	21.46
2032	-	9.56	-	10.61	-	19.47	-	21.42

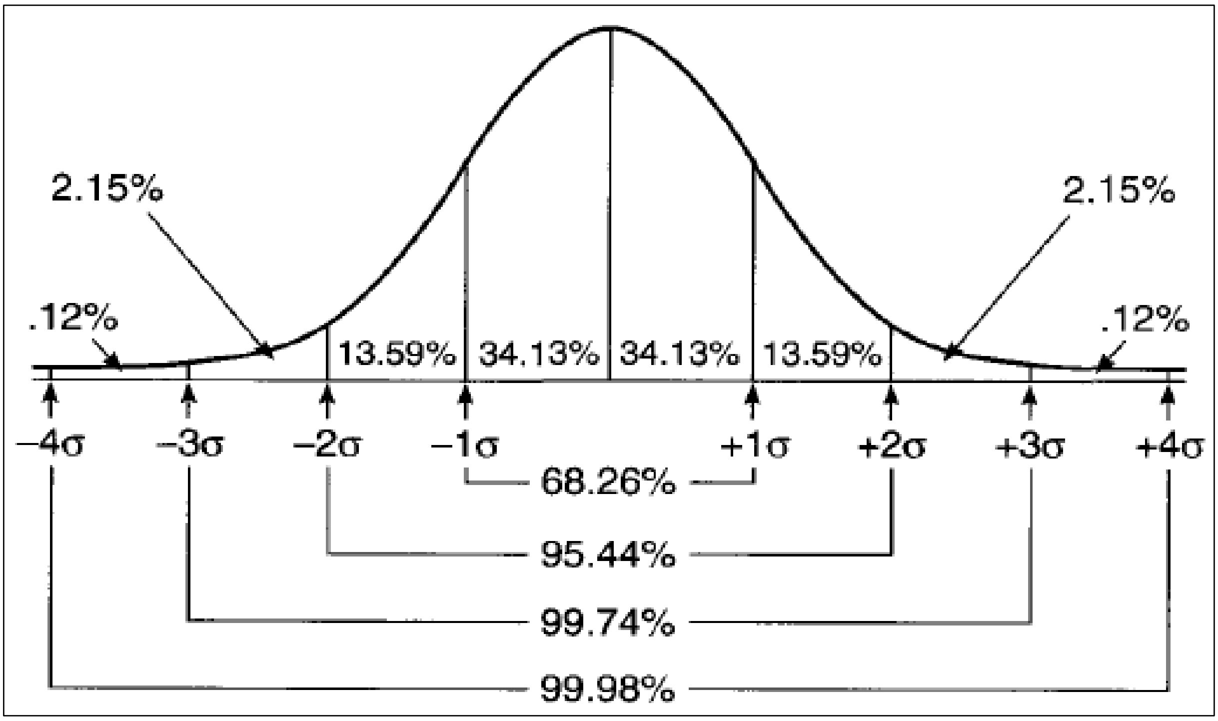


Figure 6. Spread of data with standard normal distribution. Source: Best and Kahn (2006).

Table 6. Spread of data with standard normal distribution

		Men's 100m Gold Medalist	Women's 100m Gold Medalist	Men's 200m Gold Medalist	Women's 200m Gold Medalist
N		19	18	19	19
Normal Parameters[a]	Mean	10.0084	11.0356	20.0158	22.4284
	Std. Deviation	.23677	.34261	.48629	.86988
Most Extreme Differences	Absolute	.146	.226	.092	.204
	Positive	.146	.226	.092	.204
	Negative	-.084	-.107	-.082	-.109
Kolmogorov-Smirnov Z		.635	.960	.403	.889
Asymp. Sig. (2-tailed)		.814	.316	.997	.407
a. Test distribution is Normal.					

3.5. Analysis of World Records of 100 and 200 Meters Running Championship

Athletes' purpose in participating in running championships, besides winning gold medals, is also to make a new world record. The collected data show that the time records made gotten smaller and smaller and in the last several Olympic Games events are not much different. The question is then is time improvement as new world records will always be made? Or, will there be a minimum time record that is not likely to be improved anymore? If the answer is yes, it is not impossible that male and female athletes will compete in the same championships. This is the case since male and female athletes will have the same minimum time record.

As an illustration, for 100- meters running championship for males, the minimum (fastest) time record for males was 9.63 seconds, made at 2012 in Olympic Games in London by Usain Bolt from Jamaica (Table 1). Bolt improved his own record at 9.69 in Olympic Games 2008 in Beijing. Would Bolt's best time record of 9.63 seconds be likely to be broken by other athletes in the future? Olympic Games 2016 and 2020 were evidently unable to break Bolt's world record. If Bolt's record was successfully improved, would such an improved record be continuously improved or would there be a minimum time record that was unlikely to be improved anymore?

To answer the question, the following measures were made: (1) hypothesis test on whether time records of 100 meters running championship for males is derived from the normally distributed population; and (2) review of box-plot diagram for an illustration of data distribution.

3.6. Analysis of Running Championship World Records with Normal Distribution

The data which follow a normally distributed spread will be symmetrical with the symmetrical axis being the mean value. If the data are completely normally distributed (Figure 6), the mean value is equal to the median and mode. The data distribution is measured from mean value leftwards and rightwards with standard deviation (s).

If a change is determined that it is unlikely for a runner to achieve the fastest time higher than 5% and 4.56% (Figure 6), the fastest time is

$$\text{fastest time} = \text{mean} - 1.645s \qquad (10)$$

$$\text{fastest time} = \text{mean} - 2.000s \qquad (11)$$

The Kolmogorov-Smirnov test with one sample results in asymp. sig (2-tailed) value of 0.814 (Table 6) and it is concluded that the time records data in 100- meter running championship for males are derived from a normally distributed population. The same conclusion is obtained for time records in 100 meters running championship for females and 200 meters for both males and females (Table 6). Based on the results of this hypothesis test, we can proceed to determine the fastest time that can be achieved by runners in 100- meter running championships.

Based on Figure 2, the mean and standard deviation are respectively 10.01 and 0.24. The maximum and minimum values are consecutively 10.50 and 9.63 with a range of 0.87. If a 95% chance is taken, the fastest time record calculated using (10) is:

$$\text{fastest time} = 10.01 - (1.645 \times 0.24) = 9.62$$

By taking 95.44% chance, the fastest time record calculated using (11) is:

$$\text{fastest time} = 10.01 - (2 \times 0.24) = 9.53$$

The two calculation results (9.62 and 9.53) are still not achieved by any runner. The current best time record is 9.63 seconds. Therefore, there is still a possibility to break the world record made by Usain Bolt.

By using the same method, the fastest time records are obtained for 100- meter running championship for females and 200 meters for both males and females as follows:

1. For 95% chance, the fastest time record is calculated using (10)

$$11.04 - (1.645 \times 0.34) = 10.48 \text{ (100 meters for female)}$$

$$20.02 - (1.645 \times 0.49) = 19.21 \text{ (200 meters for male)}$$

$$22.43 - (1.645 \times 0.87) = 21.00 \text{ (200 meters for female)}$$

2. For 95.44% chance, the fastest time record is calculated using Equation (11)

$$11.04 - (2 \times 0.34) = 10.36 \text{ (100 meters for female)}$$

$$20.02 - (2 \times 0.49) = 19.04 \text{ (200 meters for male)}$$

$$22.43 - (2 \times 0.87) = 20.69 \text{ (200 meters for female)}$$

Based on Table 2 and Table 5, the fastest time record for 100- meter running championship for a female is 10.61 seconds and for 200- meter running championships for both males and females are consecutively 19.30 seconds and 21.34 seconds. Compared to the results of statistical calculation, the fastest time records can still be improved.

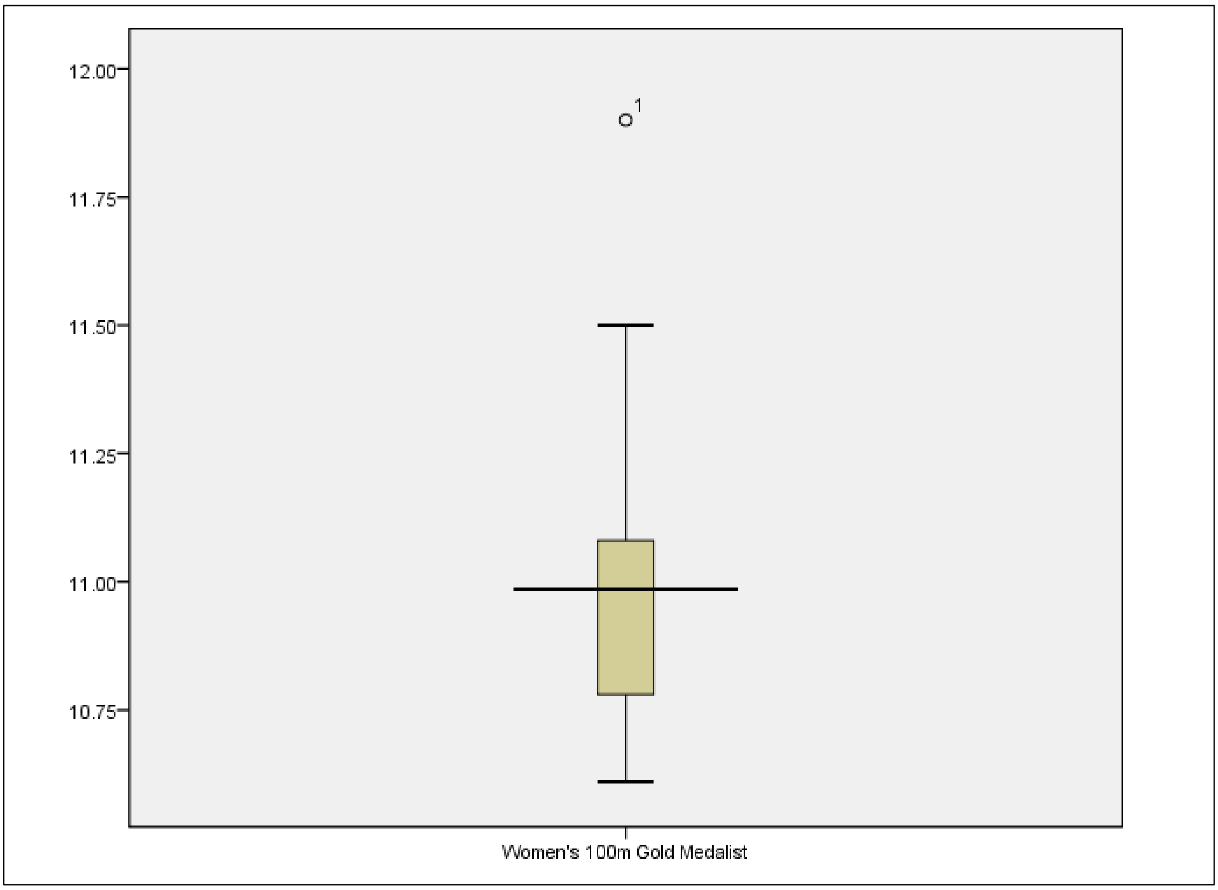
3.7. Analysis of Running Championship World Record with Box-Plot Diagram

For the four box-plot diagram in Fig. 7, the data are spread rightwards more or towards the data values higher than the median. To determine the minimum (fastest) time, the rightwards and leftwards spread data must be equal. This means that the difference between the maximum data and the median is equal to the difference between the median and the minimum data.

Table 7 summarizes the maximum, minimum and median data for each category of championship. The data are summarized in Table 1 and Table 3. However, from the box-plot diagrams for time records of 100 meters for females and 200 meters for both males and females there are top outlier data, and the top outlier data are set aside from this analysis. Consequently, there is a change to the maximum used and in Table 7 the maximum data used in the analysis are data that are non-top outlier and square bracketed.

Based on Table 7, for 100- meters running championship for males the spread of maximum data towards the median is 10.50 – 9.96 = 0.54. Meanwhile, the spread of minimum data from the median is 9.96 – 9.63 = 0.33. By assuming that the median is not changed and the spread of data towards the minimum value data is equal to the spread from the median towards the maximum value data, the maximum data that can be obtained is 9.96 – 0.54 = 9.42. Therefore, based on the box-plot diagram, there is a possibility to break Usain Bolt's world record.


10.60
10.40
10.20
10.00
9.80
9.60
Men's 100m Gold Medalist


12.00
11.75
11.50
11.25
11.00
10.75
1
Women's 100m Gold Medalist

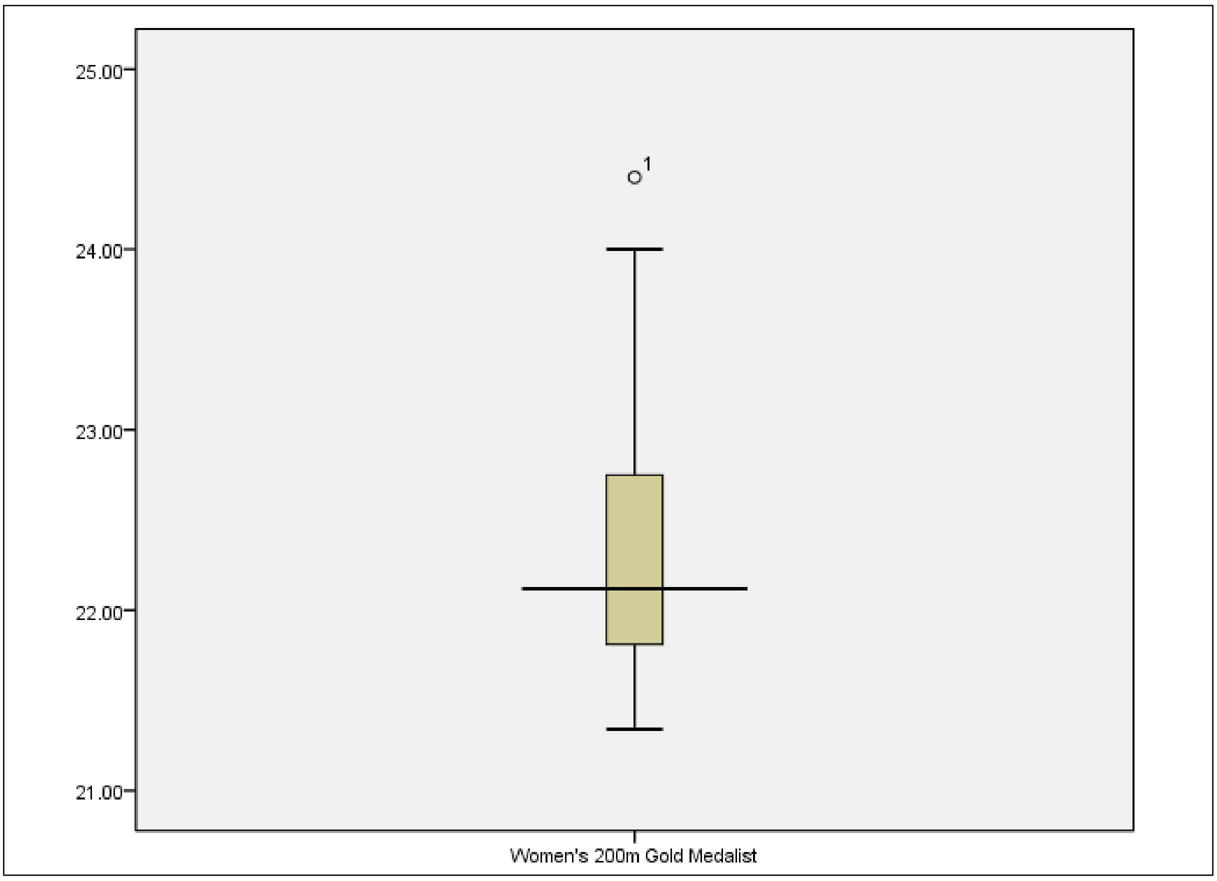


Figure 7. Spread of data with box-plot diagram

Table 7. Maximum, minimum and median time records for each category of champions (in seconds)

	100 Meters for Male	100 Meters for Female	200 Meters for Male	200 Meters for Female
Top-Outlier	-	11.90	21.10	21.10
Maximum	10.50	[11.50]	[20.70]	[24.00]
Median	9.96	10.99	20.00	22.12
Minimum	9.63	10.61	19.30	21.34

With the same method, the minimum time will be obtained for 100- meter running championship for females, 200 meters for males and 200 meters for females consecutively 10.48 seconds, 19.30 seconds, and 20.24 seconds. These results show that for 200- meter running championship for males the best time record has been reached at 19.30 seconds. Meanwhile, for 100 meter running championships for males and females and 200 meters for females, the time records can still be improved.

4. Conclusions

One of the important benefits of the mathematical model is to make a reliable and useful prediction. The problem solved in this article is determining the most appropriate mathematical model for 100 and 200 meter running championships for both males and females for the worldwide championship in Olympic game events. The model obtained was used to predict the time record made by athletes in the next Olympic game events. The mathematical equation that suits the most for 100 meter running championship for males is the logarithmic regression model, while 100- meter running championships for females and 200 meters for both males and females are modeled using simple linear regression. Based on the four models obtained, the time record prediction in the next Olympic game events will get lower and lower. However, such a prediction is only made for the short run that is for the next three Olympic game events. From the prediction results, time improvement can be made in a very strict range of 0.02 – 0.06 seconds.

The current world record for 100 meter running championship held by Usain Bolt (9.63 seconds) will always be improved in the future. Assuming that the time record is normally distributed, the fastest record in 100 meters running championship is 9.62 seconds with 5% chance and 9.53 seconds with 4.6% chance. If the time record of 9.53 seconds is reached, there will be no more improvement in the world record. However, if the analysis is conducted using the box-plot diagram, the minimum time is 9.42 seconds.

For 100- meter running championship for females, the current record of 10.61 seconds held by Elaine Thompson-Herah from Jamaica is still possibly improved, by assuming the result of the normal distribution is 10.48 seconds (with 0.05 chance) or 10.36 seconds (with 0.046 chance). If the analysis is conducted using the box-plot diagram, the result is 10.48 seconds.

The best world record for 200- meter running championship for males is currently held by Usain Bolt from Jamaica at 19.30 seconds. The result of the analysis with normal distribution concludes that there is a possible time improvement of 19.21 (with 0.05 chance) or 19.04 seconds (with 0.046 chances). If the analysis is conducted using the box-plot diagram the result is 19.30 seconds. The time record made from the result of calculation using box-plot diagram has been achieved by Usain Bolt.

The final conclusion for 200- meter running championship for females with the current best time record is held by Florence Griffith Joyner from the United States at 21.34 seconds. The best time can still be improved until 21.00 seconds (with 0.05 chance) or 20.69 seconds (with 0.046 chances). Analysis using box-plot diagram results in 20.24 seconds.

For suggestion, based on the research results, it is expected that the logarithmic regression model and linear regression will have asymptotes at a certain limit. In the logistic model, the limit is called carrying capacity. Therefore, it is possible to model the data used in this research by building a reverse logistic model that is opposite to the existing logistic model. Furthermore, the SA method [13] and the ISA method [12] can be used to generate the regression equation in the problem discussed in this article.

Acknowledgements

The authors are acknowledging the financial support from grants of SK No. B/1729/UN23.18/PN.01/2022 and Kontrak Penelitian RDU No. T/530/UN23.18/PT.01.03/2022 from LPPM Universitas Jenderal Soedirman, Purwokerto, Indonesia.

REFERENCES

[1] T. Arnold and T. Godbey. Introducing linear regression: an example using basketball statistics. Journal of Economics and Finance Education, Vol. 11, No. 2, 113-130, 2012.

[2] J. W. Best and J. V. Kahn. *Research in Education, 10th. Ed*., *P*earson *Education* Inc., South African, 2006.

[3] J. Hao and Y. Zhang. Sports competition results predict a linear regression model applied research. Bio Technology, Vol. 8, No. 9, 1199-1204, 2013.

[4] Online Available: https://www.statista.com/statistics/1090316/olympics-100m-gold-medal-times-since-1896/ [August 8, 2021].

[5] Online Available: https://www.statista.com/statistics/1091753/olympics-200m-gold-medal-times-since-1900/ [August 8, 2021].

[6] D. Lapresa, J. Arana, M. T. Anguera, I. Perez-Castellanos, and Y. M. Amatria. Application of logistic regression models in observational methodology: game formats in grassroots football in initiation into football. Anales de Psicologia, Vol. 32, No. 1, 288-294, 2016.

[7] R. K. Mishra and M. Kaur. Mathematical modeling approach to predict athletic time performance. Universal Journal of Applied Mathematics, Vol. 1, No. 4, 242-246, 2013.

[8] J. Sarwono. Mixed Methods: Cara Menggabung Riset Kuantitatif dan Riset Kualitatif Secara Benar [Mixed Methods: How to Properly Combine Quantitative and Qualitative Research], Elex Media Komputindo, Indonesia, 2011.

[9] Sugiyono. Metode Penelitian Bisnis: Pendekatan Kuantitatif, Kualitatif dan R & D) [Business Research Method: Quantitative, Qualitative, and R&D Approach)], Alfabeta, Indonesia, 2010.

[10] H. Vandewalle. 2017. Mathematical modeling of the running performances in endurance exercise: comparison of the model of Kennelly and Peronnet-Thibault for world records and elite endurance runners. American Journal of Engineering Research, Vol. 6, No. 9, 317-323, 2017.

[11] W. Woodside. The Optimal Strategy for running a race (a mathematical model for world records from 50 m to 275 km). Mathematics and Computing Modelling, Vol. 15, No. 10, 1-12, 1991.

[12] Jetsada Singthongchai, Noppakun Thongmal, Nirun Nitisuk (2021). An Improved Simple Averaging Approach for Estimating Parameters in Simple Linear Regression Model. Mathematics and Statistics, 9(6), 939–946. https://doi.org/10.13189/ms.2021.090610.

[13] Agung Prabowo, Agus Sugandha, Agustini Tripena, Mustafa Mamat., Sukono, Ruly Budinono. (2020). A New Method to Estimate Parameters in the Simple Regression Linear Equation. Mathematics and Statistics, 8(2), 75–81. https://doi.org/10.13189/ms.2020.080201.