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DATA ANALYSIS IN SHORT TRACK SPEED SKATING

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Abstract

Data analysis in short track speed skating has become a crucial tool for improving athlete performance, optimizing training strategies, and enhancing competitive outcomes. This study explores the application of data-driven techniques in short-track speed skating, focusing on performance metrics including lap times, split times, acceleration, and biomechanical efficiency. By leveraging sensors, motion capture systems, and wearable technology, coaches and analysts can collect real-time data on skaters' movements, allowing for detailed analysis of stroke mechanics, glide phases, and cornering techniques. The integration of this data into performance modeling helps identify strengths and weaknesses, fine-tune race strategies, and predict potential outcomes under specific conditions. Additionally, machine learning algorithms are increasingly being employed to predict injury risk and optimize training regimens. This paper discusses methods of data collection and analysis, and the practical applications of the insights gained, highlighting the potential to improve both individual and team performance in short-track speed skating. Ultimately, data analysis in this domain offers a significant competitive edge, driving the evolution of techniques and advancing sport to new levels of precision and excellence.

Keywords: *data analysis, performance optimization, short track speed skating, biomechanics*

INTRODUCTION

Short track speed skating is an exciting and dynamic sport in which the perfect harmony of speed, strength, and technique determines success (FORMENTI - MINETTI, 2007; HETTINGA et al., 2016). Athletes' constant pursuit of improvement and the professional support provided by coaches are strongly supported by various performance diagnostic methods, which play a key role in elite sport development (KONINGS et al., 2015; BRIAND et al., 2022). These methods allow for a detailed assessment of athletes' physical condition, performance potential, and technical or physiological limitations, thereby supporting targeted performance enhancement and injury prevention (BENEKE et al., 2011; SHAFFER-GINSBERG, 2017).
Considering the challenges of modern times, advances in technology and sports science have enabled the performance of short-track speed skaters to be analyzed with increasing precision and depth (IMRE, 2023; BRIAND et al., 2022). The research presented here and the resulting data are vital to the continued development of sport. Performance diagnostics provide feedback not only for athletes and coaches but also valuable datasets for applied sports science research (STEPHENSON et al., 2021). The analyses applied in this study—such as the Wingate Anaerobic Test, spinal condition assessment, and the

measurement of ground contact forces and weight distribution during treadmill walking and running—contribute directly to the optimization of individualized training programs (BENEKE et al., 2002; KARABA JAKOVLJEVIĆ et al., 2018; VAN DER KRUK et al., 2018).

Behind the success in short-track speed skating lies extensive work, long-term commitment, and scientific rigor. Performance optimization is a continuously evolving field in which even minor physiological or biomechanical adjustments can have a decisive effect on competitive outcomes (NOORDHOF et al., 2017; KUPER-STERKEN, 2003). The scientific foundation of training programs, combined with continuous monitoring of athletes' physical and mental condition, is indispensable for reaching peak performance (DONG, 2016; MC CRATY - SHAFFER, 2015). The integration of research findings with practical coaching experience opens new pathways for the future development of sport (IMRE, 2018).

In this context, the present article aims to provide a comprehensive overview of the importance of physical diagnostic methods, the potential of physical analysis of athletes, and the scientific development of training strategies in short-track speed skating. The data and analyses presented demonstrate that the application of modern technology and evidence-based sports science can significantly enhance athletes' physical performance and support long-term athletic development (HETTINGA et al., 2016; KONINGS et al., 2015). Proper interpretation of diagnostic results is essential not only for performance optimization but also for injury prevention and load management (BOSQUET et al., 2001; BRIAND et al., 2022). Physical analysis helps identify individual weaknesses and highlight strengths that can be further developed (PEREZ-GOMEZ et al., 2007).

In a sport where fractions of a second determine competitive success, precise physiological and biomechanical adjustments are essential. When evaluating performance diagnostic data, a multidisciplinary approach is paramount, as close cooperation among coaches, sports scientists, physiotherapists, and athletes yields the most effective outcomes (STEPHENSON et al., 2021). A well-organized and successful sports team can no longer operate without systematic data analysis and performance diagnostics, and short track speed skating is no exception (PERFORMANCE DIAGNOSTICS IN THE SERVICE OF HUNGARIAN SHORT TRACK SPEED SKATING TEAM, 2011–2022).

The purpose of this research was to analyze the diagnostic methods, specialized equipment, and applied monitoring systems used by the Hungarian National Short Track Speed Skating Team (n = 16), as well as to evaluate their performance diagnostic outcomes (PERFORMANCE DIAGNOSTICS TEAM MEDICAL REPORT, 2022). The study focused on examining the relationships between body composition (muscle mass percentage), blood lactate concentration, autonomic regulation (HRV LF/HF%), explosive power (Wingate 5-second peak power W/kg and 500 m skating time), and individual skate setup parameters during the final phase of the Beijing Olympic cycle (May–December 2021) (BENEKE et al., 2011; TARVAINEN et al., 2014; IIZUKA et al., 2020).

Quantitative statistical methods, including analysis of variance (ANOVA) and correlation analysis, were applied to explore relationships between physiological variables and performance indicators. Results are presented with appropriate levels of statistical significance to ensure objective hypothesis testing. We focused on individual characteristics such as age, sex, fitness level, and adaptive capacity, which are known to influence performance and training responsiveness (TANAKA et al., 2001; WHYTE et al., 2008; SUZIC LAZIC et al., 2017).

The primary hypothesis of the study was that average power output measured during the Wingate Anaerobic Test (AVG power, W/kg) shows a positive correlation with 500-meter short track speed skating performance, indicating that athletes with higher average anaerobic power achieve faster race times (BENEKE et al., 2002; GALÁN-RIOJA et al., 2020).

MATERIAL AND METHODS

The purpose of the research methodology chapter is to present in detail the procedures used in this study, which enabled the examination of short-track speed skaters' performance and the correlations among different biological markers. In this chapter, we describe the criteria for selecting the participants, the measurement tools and techniques used, and the methods of data collection and analysis.

The research explores the relationships between physiological and performance variables in short-track speed skating. The investigated variables include body composition, maximal lactate level, the state of the autonomic nervous system (HRV LF/HF ratio), and Wingate test results. These variables can be crucial for evaluating athletes' training status and competition performance. Below, we introduce the research methodology, including the statistical techniques and analysis strategies used to evaluate the results.

The participants in the study were members of the Hungarian National Short Track Speed Skating Team, selected by the Hungarian National Skating Federation. This sample provided an opportunity to analyze the performance and physiological parameters of athletes competing at the short-track speed skating level. During participant selection, an important criterion was active participation in international competitions, as this guarantees a high level of fitness and competitiveness. Using the sample was a gratifying experience, as the team's measurements fundamentally contributed to the success of the research and the relevance of the results.

The data collection process was carried out systematically and in accordance with predetermined protocols. The measurements were carried out during training sessions outside the competition season to minimize the disturbing effects of external factors. The data was analyzed using quantitative methods. During the statistical processing, we primarily used analysis of variance (ANOVA) and correlation analyses to test hypotheses and explore relationships. During data analysis, we ensured the statistical significance and the interpretation of the results were correct. To present the results, we used statistical software (JASP and SPSS) to support the visual display of data and the clear

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presentation of complex relationships. The Department of Performance Diagnostics assisted with data collection at the National Institute for Sports Medicine, Hungary.

RESULTS

The preparations for the 2022 Winter Olympics required an intensive training period and thorough performance analysis for the Hungarian short-track speed skating team, as reflected in the attached tables and charts. Monitoring athletes' physical condition and progress is indispensable for achieving Olympic success, as even the most minor technical and physical details can make a difference in world-class competition.

The table presents the athletes' Wingate test results for maximum power output, expressed in watts per kilogram (W/kg), a key indicator of explosiveness and anaerobic performance. The results of the Wingate test are significant in short-track speed skating, where quick starts and sprints are crucial in competition. The results achieved by the athletes indicate the effectiveness of the training work and changes in their physical condition.

Reviewing the table, it is apparent that the athletes' performance generally improves over time. Higher W/kg values indicate that athletes can exert greater force relative to their body weight, which is vital for speed and physical fitness. Based on the data, the majority of athletes gradually improved their performance, suggesting that the training programs were effective in enhancing physical condition. Visualization, through chart representation, further clarifies that a group of athletes stands out from the rest, indicating that they responded particularly well to the training stimuli. Evaluating the results, special attention should be given to the athletes who achieved the highest power outputs, who consistently reached high W/kg values over the period.

The analysis and evaluation of such data not only help understand athletes' current state but also provide fundamental information for fine-tuning training methods and strategies. Individual variations and performance fluctuations within the given period must be considered in training planning. Athletes who showed less improvement or potentially stagnant or declining performance may require additional attention and potentially modified training plans.

When analyzing the data, external factors such as injuries, competition loads, and psychological impacts on performance should also be considered.

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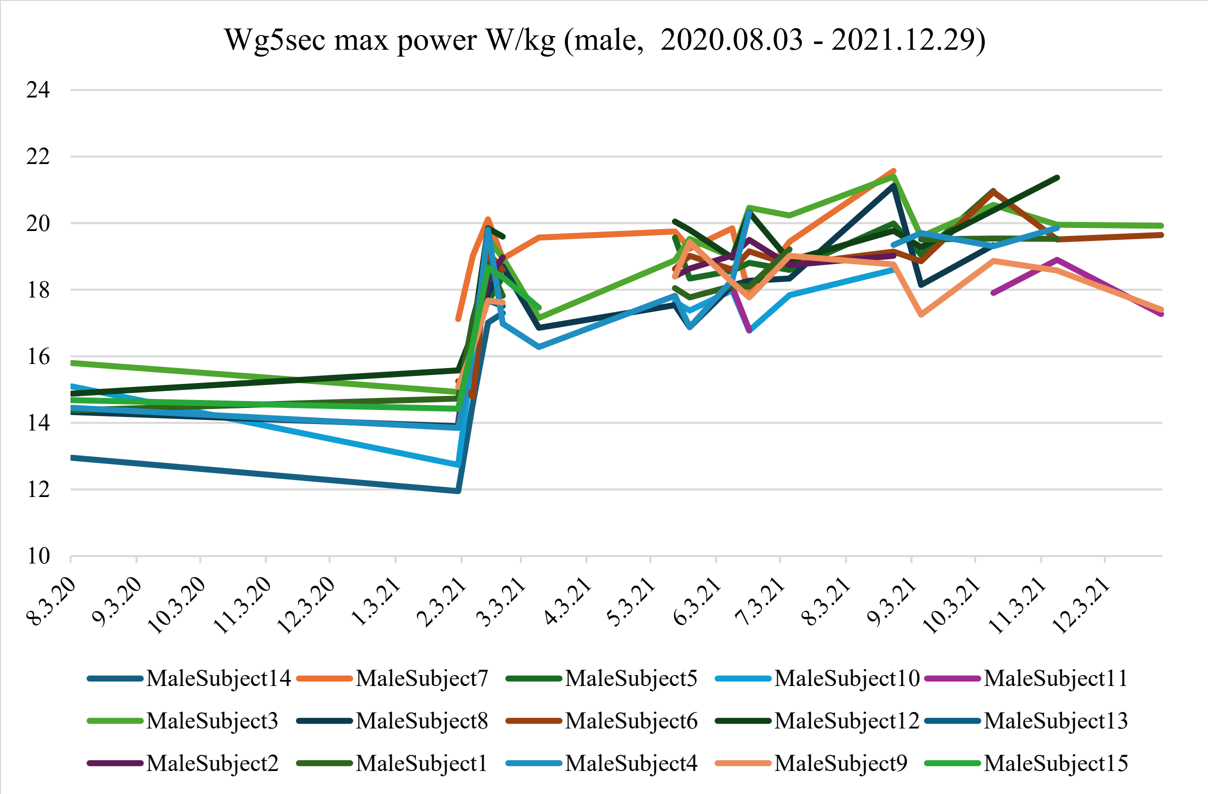

Figure 1: Development of Maximal Exertion During Winter Olympic Preparation - Wingate Test Results (2020.08.03 - 2021.12.29).
Source: own editing

The examination of charts reveals significant variability in male athletes' performance outcomes throughout the year. The average time results show a gradual decline, suggesting potential performance improvement as the competition season progresses. Alongside average results, it is crucial to consider the minimum and maximum values, which provide insights into the team's performance spectrum. In male athletes, the range between the minimum and maximum time results is generally narrower, suggesting that individual performances are more closely aligned and that the team performs more consistently overall.

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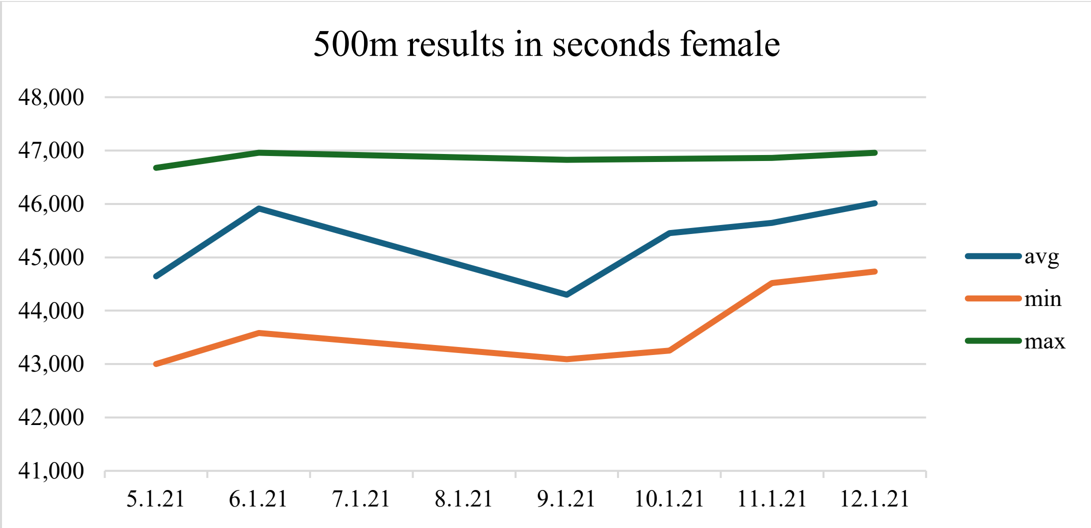

Figure 2: Changes in Performance Over Time: Performance of Female Speed Skaters. Source: own editing

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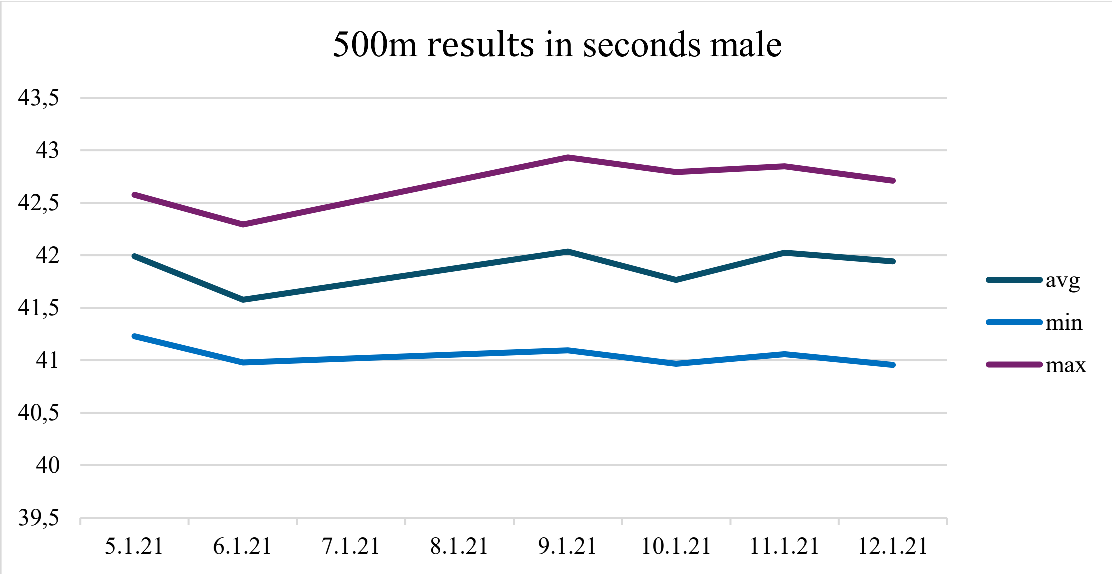

Figure 3: Average, Minimum, and Maximum 500m Results of the Men's Speed Skating Team
Source: own editing

The data for female athletes indicate that their race times are, on average, slightly higher than those of their male counterparts, which is not surprising given physiological and biomechanical differences. Here, the gap between the minimum and maximum values is wider, suggesting greater variability in performance among female athletes. For both males and females, the significant decrease in minimum values could indicate an intensification of competitive dynamics. By the end of the period, an improving trend is evident in both genders, which may reflect the effectiveness of the training program and improved athletes' physical condition.

Further examination of the charts reveals periodic fluctuations in the average performance of female athletes, suggesting cycles of training, competition preparation, and rest. The results show that the best (minimum) times typically appear just before competition periods, suggesting that peak conditioning was appropriately timed. For female athletes, data from September 2021 show notable improvement, suggesting the need for fine-tuning before the competition season.

On the other hand, the data for male athletes are more stable, with less fluctuation, suggesting that the men's training program is less variable or that the athletes' physical condition is more consistently maintained throughout the year. However, the absence of fluctuations does not necessarily mean there is no room for improvement; instead, it suggests that male athletes are performing consistent training, which allows them to deliver steady performance.

The presentation of the data clearly demonstrates that training programs, rest, and recovery strategies play a key role in shaping athletes' performances. Furthermore, psychological factors such as mental preparation for competitions or stress management techniques can also influence time results.

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However, 500-meter speed skating is not solely about physical and mental preparation; technical skills and ice conditions can also significantly affect the outcomes. Therefore, it is vital that athletes' training programs also focus on technical development to optimize their movement on the ice and improve the efficiency of their turns. Development of these technical elements can fine-tune performance and enhance competition results.

DISCUSSION

The purpose of this research was to explore the relationships between body composition, lactate level, the HRV LF/HF ratio indicating the state of the autonomic nervous system, the results of the Wingate test measuring explosiveness, and the 500-meter short-track speed skating competition times in the last phase of the Beijing Olympic cycle. Our results revealed relationships between different variables that may be relevant when planning interventions to improve sports performance.

The positive correlation between average power measured during the Wingate test (AVG power W/kg) and 500m speed skating time is consistent with previous research showing that greater anaerobic capacity can improve short-term performance in sports where explosiveness and speed are decisive factors (SMITH-ROBERTS, 2015). This correlation supports the assumption that better anaerobic endurance contributes to faster 500m times, which may be particularly important for speed skating competitors, where every millisecond counts.

This hypothesis has been supported. Measuring athletes' performance requires a multidimensional approach, with strength and speed as critical variables. Below, we present a regression analysis to examine the relationship between Wingate test results and 500-meter speed skating times. We performed a regression analysis. When setting up the analysis framework, the data were organized as follows: each athlete's name was followed by two series of numbers, one representing the power meter (Wingate test results) data, and the other representing their 500-meter time results in seconds. Initially, a summary output is presented that provides an overview of the regression statistics.

Table 1: Regression statistics Wingate and 500m results.

Regression Statistics	
Multiple R	0,60540814
R Square	0,36651902
Adjusted R-Square	0,358292
Standard Error	1,51652778
Observations	79

Source: own editing

Based on the regression statistics, the correlation coefficient between the power meter (Wingate) and the speed meter (500m time) is moderate, suggesting a relationship exists between the two variables, but it is not strictly deterministic. The R-squared value indicates that the results of the Wingate test alone explain approximately 36.5% of the variability in the 500-meter times. A higher R-squared suggests that the power meter results more strongly determine the speed outcomes, while a lower value indicates that additional factors also play a role. The ANOVA (Analysis of Variance) section provides a statistical test to confirm the significance of the relationship.

Table 2: ANOVA

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	102,460013	102,460013	44,5506111	3,4114E-09
Residual	77	177,088952	2,29985652		
Total	78	279,548965			

Source: own editing

The F-value and the significance level (Significance) in the ANOVA table show that the relationship between the power meter (Wingate) and the speed meter (500m time) is statistically significant. Subsequently, the table in the coefficients section illustrates how each unit increase in the X variable (Wingate performance) affects the expected value of the Y variable (500m time).

Table 3: Regression coefficients

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Inter cept	54,78	1,75	31,39	1,24284236654967E-45	51,30	58,25	51,30	58,25
X Variable 1	-1,03	0,15	-6,67	3,41143227893385E-09	-1,34	-0,72	-1,34	-0,72

Source: own editing

This model suggests that every 1 W/kg increase in Wingate test performance results in an average decrease of 1.028 seconds in the 500-meter time. The next step in the analysis involves transitioning to graphical representations that visually illustrate the relationship between the variables and help assess the fit quality of the modeled relationship.

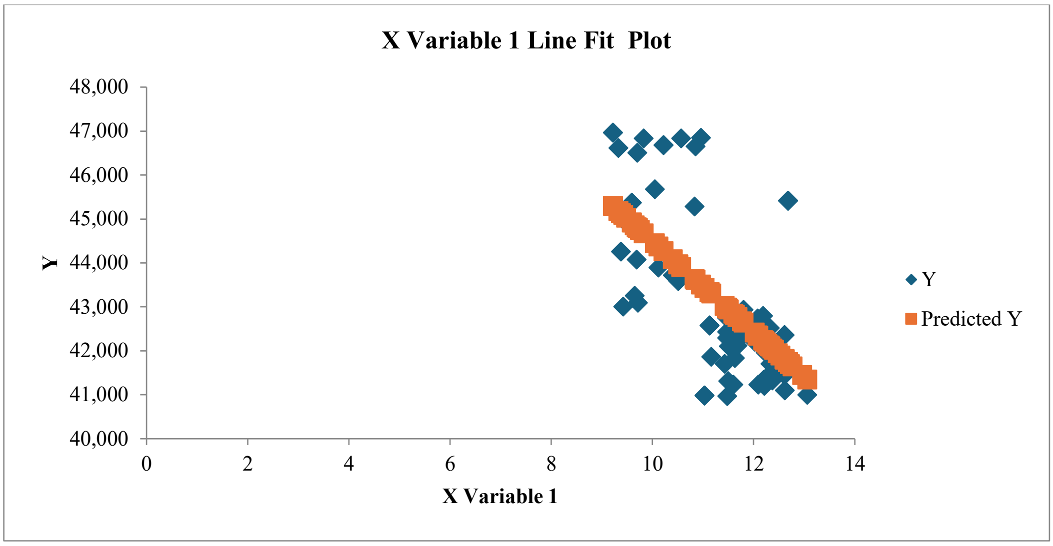

Figure 4: X Variable 1 Line Fit Plot.
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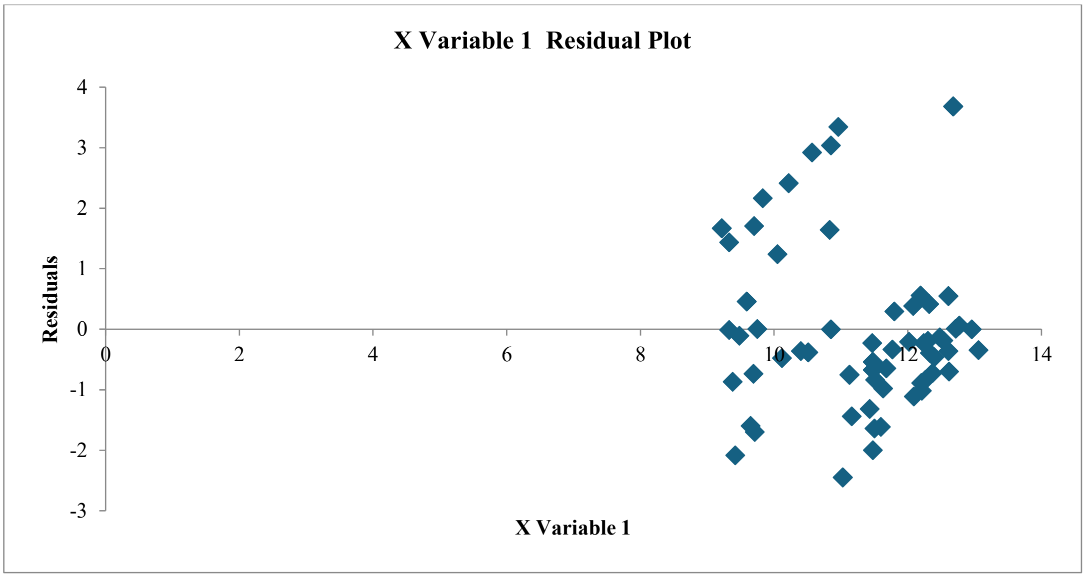

Figure 5: X Variable 1 Residual Plot.
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The Line Fit Plot shows a comparison between predicted and observed values. At the same time, the Residual Plot displays the distribution of residual errors, i.e., the differences between the model and the actual data.

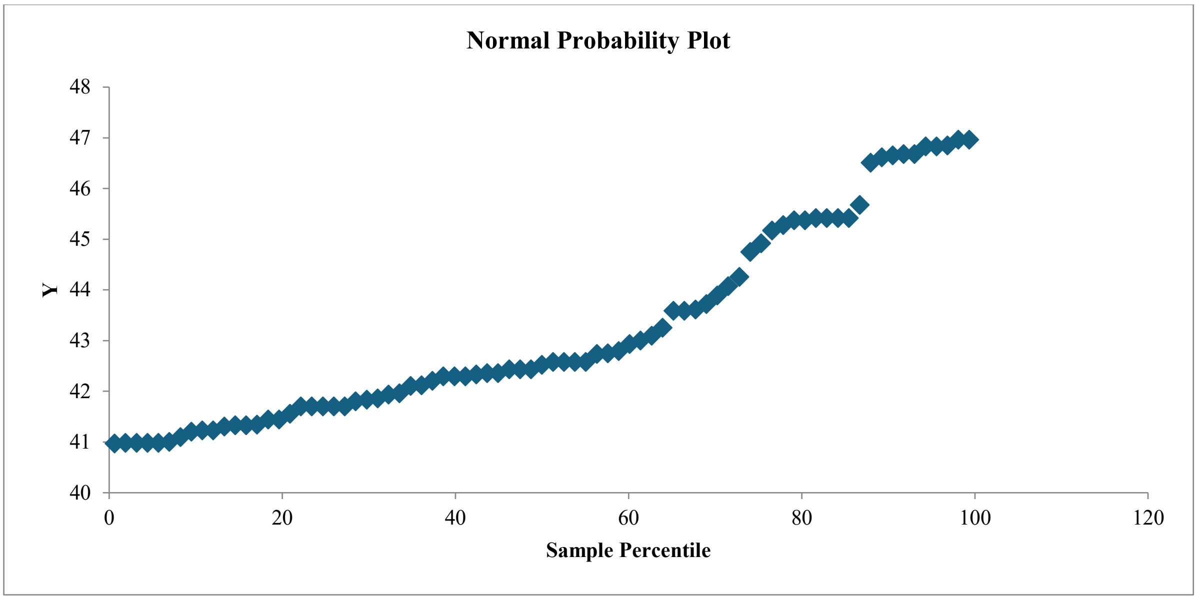

Figure 6: Normal Probability Plot.
Source: own editing

Finally, the Normal Probability Plot assesses whether the data are approximately normally distributed, an important precondition for classical linear regression analysis. Summarizing the results of the regression analysis, the relationship between Wingate performance and 500-meter speed skating times is significant, though the degree of correlation is moderate. The findings suggest that higher power meter performance likely improves speed performance, but further examination of additional variables is needed to understand the relationship fully.

This research aimed primarily to investigate the relationships among body composition, lactate levels, autonomic nervous system status as indicated by the HRV LF/HF ratio, explosiveness as measured by the Wingate test, and 500-meter short-track speed skating times. During the study, Iwe tested three hypotheses regarding the relationships between sports performance and biological markers.

Our hypothesis, which proposed that the average power measured during the Wingate test (AVG power W/kg) positively correlates with 500-meter speed skating times, was confirmed. This outcome is consistent with previous studies demonstrating that anaerobic capacity significantly influences short-duration sports performance (SMITH-ROBERTS, 2015). Based on these findings, short-track speed skating training programs should place greater emphasis on anaerobic conditioning, which could enhance athletes' explosiveness and performance at critical moments.

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