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Original Article

Technical factors associated with competitive success in elite men's free skating at the ISU World Championships (2023–2026)

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Abstract
Problem Statement. The increasing technical complexity of elite men's figure skating has increasingly prompted the need to identify the performance factors that contribute most substantially to competitive success under the International Judging System (IJS). Although prior studies have examined individual aspects of performance, including jump difficulty, judging scores, and biomechanical characteristics, evidence integrating multiple technical performance indicators remains limited. Many investigations have relied on data from a single competition or a restricted number of athletes, which limits the generalizability of their findings. **Approach.** A retrospective observational study was conducted using official International Skating Union (ISU) protocols from the World Figure Skating Championships held between 2023 and 2026. The sample comprised 96 free skating performances by all skaters who qualified for that segment. Spearman's rank correlation analysis was employed to assess the relationships between individual technical variables and the Total Segment Score (TSS). Multiple linear regression analysis was subsequently performed to identify the independent technical predictors of competitive success. **Purpose.** This study aims to determine the independent contribution of technical performance indicators to competitive success in elite men's figure skating. **Results.** The final regression model explained 78.8% of the variance in the Total Segment Score ($R^2 = 0.788$). The number of clean quadruple jumps emerged as the strongest independent predictor of competitive performance, followed by the number of clean triple jumps, mean spin level, step sequence level, and the number of falls. Correlation analysis further demonstrated significant positive associations between the Total Segment Score and Base Value, Grade of Execution, clean quadruple jumps, mean spin level, and step sequence level. In contrast, falls and several execution errors were negatively associated with competitive performance. **Conclusions.** The findings demonstrate that competitive success in elite men's figure skating depends not only on technical difficulty but also on the consistent execution and quality of technical elements throughout the program. Clean execution of quadruple and triple jumps, high spin and step sequence levels, and avoidance of falls are key factors in success at the World Championship level. These findings provide evidence-based guidance for coaches and athletes in optimizing program composition, technical preparation, and training strategies, while also contributing to a fuller understanding of the technical factors associated with elite competitive performance.
Keywords: **elite men's figure skating; competitive success; technical performance; International Judging System (IJS); performance analysis.**

Introduction

The introduction of the International Judging System (IJS) by the International Skating Union (ISU) in 2004 fundamentally transformed the scoring of figure skating, replacing the traditional 6.0 system with a structured framework that independently evaluates technical elements and program components. This reform improved the objectivity of judging and established a sound framework for the quantitative analysis of competitive performance (Ji, 2022; Yordanova, 2022; ISU, 2024a). In contemporary sport science, the analysis of official IJS competition protocols has become a well-established method for investigating the factors underlying competitive success. Previous studies have shown that this approach allows for the evaluation of the relative contribution of technical performance indicators and program components to final competitive outcomes among elite figure skaters (Yordanova, 2022).

Over the past two decades, elite men's figure skating has undergone remarkable technical progression, with quadruple jumps becoming an increasingly decisive factor in competitive success, as demonstrated by analyses of European and World Championship competitions (Rauer et al., 2022). The successful execution of the quadruple Axel represents the current frontier of technical achievement in the sport, requiring exceptional biomechanical efficiency and highly developed athletic capacity (Hirosawa, 2026). Sezganov and Eryomina (2023) further documented this trend by reporting a continued increase in the technical complexity of men's free skating programs during the 2017–2022 seasons, driven primarily by the growing incorporation of quadruple jumps and the optimization of their Base Value.

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The increasing technical demands of figure skating have also highlighted the importance of the physical and biomechanical factors underlying elite performance (Gugu Gugu-Gramnatopol et al., 2017; Hirosawa et al., 2022; Yordanova et al., 2023). Consequently, contemporary research increasingly incorporates kinematic, kinetic, and anthropometric measures to provide a more comprehensive understanding of the determinants of competitive performance.

At the same time, technical difficulty alone does not fully explain differences in competitive outcomes. The scoring structure of the IJS rewards both the inherent difficulty of an element and the quality with which it is performed. Therefore, an athlete who includes highly valued technical elements but executes them inconsistently may not obtain the competitive advantage expected from increased difficulty. This distinction is particularly important in men's free skating, where the growing number of quadruple jumps has raised the technical ceiling of programs while also increasing the consequences of execution errors. The relationships among technical difficulty, execution quality, and the resulting competition score therefore represent an important area for performance analysis at the elite level (Cheng & Gonzalez, 2022; Kitaeva, 2023).

As competitive programs have become increasingly complex, research has focused on identifying the performance indicators with the greatest predictive value for success. Particular attention has been given to the relationships among the Grade of Execution (GOE), the Total Element Score (TES), and the Program Component Score (PCS) (ISU, 2023a). Empirical evidence suggests that these variables provide greater predictive power for final competitive outcomes when considered collectively rather than individually (Cheng & Gonzalez, 2022). Similarly, Kitaeva's (2023) analysis of the World Championships demonstrated that increasing technical difficulty enhances the relative contribution of individual elements, ultimately leading to higher overall competition scores.

Following the ISU rule changes introduced in 2018, the expansion of the GOE scale (from ±3 to ±5) substantially increased the influence of execution quality on overall competition scores, prompting a shift in strategies for constructing competitive programs (Zhgun & Kuznetsova, 2021; Byun et al., 2026). Evidence suggests that this change has shifted the emphasis from maximizing technical difficulty to achieving precise and consistent execution of technical elements.

In this context, the evaluation of individual technical elements should also consider the contributions of spins and step sequences, which are integral parts of the free skating program. Although their Base Values are generally lower than those of quadruple jumps, their levels and execution quality contribute directly to the Total Element Score and may differentiate the performances of athletes with otherwise similar jump content. A comprehensive assessment of competitive performance should therefore take into account the full technical structure of the program, including jump content, execution quality, spin levels, step sequence levels, and deductions for errors. Such an approach may provide a more practical understanding of how elite skaters convert technical content into competitive scores.

Beyond the analysis of individual scoring components, recent research has also examined other factors influencing competitive success in men's figure skating under the IJS. Cheng and Gonzalez (2022) reported a strong linear relationship between the Total Element Score (TES) and the Program Component Score (PCS), suggesting the presence of a *difficulty bias*, whereby greater technical difficulty is associated with systematically higher component scores. Zhu (2018) demonstrated that final competition scores can be predicted with high accuracy from judges' evaluations, whereas the influence of national bias appears to be relatively limited.

Considerable research has focused on the reliability and objectivity of judging under the IJS. Collectively, these studies indicate that the system ensures a high level of judging objectivity despite limited systematic biases (Findlay & Ste-Marie, 2004; Heiniger & Mercier, 2018; Zhu, 2018; Krumer & Otto, 2022).

Modern men's figure skating is characterized by continuously increasing technical complexity, placing progressively greater demands on athletes' physical preparation (Rauer et al., 2022; Pashchenko, 2023). The successful execution of multi-rotational jumps requires high levels of maximal strength, explosive power, coordination, and dynamic postural control. Consequently, sport-specific physical preparation is widely recognized as a key factor in developing the technical proficiency required for elite-level performance (Cruz et al., 2021; Helešic & Lehnert, 2024; Yordanova et al., 2023).

Biomechanical studies have shown that the successful execution of multi-rotational jumps depends on the ability to generate optimal take-off velocity while maintaining precise technical coordination. *Evidence further indicates that jump height is positively associated with knee extensor strength* (Podolsky et al., 1990). *In contrast, take-off* velocity and post-landing flow remain key kinematic predictors of execution quality, strongly influencing the GOE awarded by the judges (Hirosawa, 2026).

These biomechanical and technical considerations underline the need to distinguish between variables that are merely associated with high scores and those that independently contribute to competitive performance when other technical indicators are considered simultaneously. Correlation analysis can identify relationships between individual performance variables and competition scores. However, it does not establish whether a particular variable retains its contribution when the effects of other related indicators are taken into account. Multiple regression analysis therefore offers an additional perspective by allowing the independent contribution of several technical indicators to be examined within a common statistical model.

Despite substantial advances in figure skating research, the available evidence remains fragmented. Most studies have focused on individual aspects of performance, such as jump difficulty or judging scores, without examining their combined contribution to competitive success. Moreover, many investigations have been based on data from a single competition or a limited number of skaters, restricting the generalizability of their findings. These limitations highlight the need for a comprehensive statistical analysis that integrates multiple performance indicators using data from four consecutive ISU World Figure Skating Championships (2023–2026).

The present study analyzed official competition protocols from four consecutive ISU World Figure Skating Championships (2023–2026) to identify the technical factors associated with competitive success.

To address this research problem, a retrospective observational design was applied using the official competition protocols from these four championships. The relationships between individual technical performance indicators and the Total Segment Score were examined using Spearman's rank correlation, and multiple linear regression was used to identify the technical indicators that independently predicted competitive performance. This combined analytical approach enabled both the assessment of individual associations and the identification of the technical factors that retained an independent contribution after accounting for the effects of other performance indicators.

This study aims to determine the independent contribution of these technical factors to competitive success in elite men's figure skating.

Materials & Methods

Study Design and Sample

This retrospective observational study analyzed official free skating protocols from the ISU World Figure Skating Championships held between 2023 and 2026. The sample comprised all skaters who qualified for the free skating segment, yielding a total of 96 competitive performances. Each performance at an individual World Championship was treated as an independent statistical observation. This approach enabled the analysis of competition performances rather than athlete-specific longitudinal changes. The dataset included 54 unique skaters. Of these, 30 competed in one championship, 11 in two, 8 in three, and 5 in all four championships. Accordingly, the statistical analysis was based on 96 competition performances rather than 96 unique athletes. Data were obtained from the official competition protocols published by the ISU. The study period was deliberately restricted to 2023–2026 because all championships were conducted under the International Judging System (IJS) using the current three-component Program Component Score (PCS) structure (Composition, Presentation, and Skating Skills) (ISU, 2022, 2023b, 2024b), ensuring methodological consistency across all analyzed performances.

Variables

For each free skating performance, the following variables were extracted from the official ISU competition protocols: final rank (Rank), Total Segment Score (TSS), Base Value (BV), Total Element Score (TES), Total Program Component Score (PCS), Grade of Execution (GOE), element execution errors, spin and step sequence levels (Levels), and deductions. All data were compiled into a database for subsequent statistical analysis, and a comprehensive overview of the included variables is presented in Table 1. The mean spin level was calculated as the arithmetic mean of the levels assigned to the three spin elements performed in the free skating program.

Table 1. Variables Included in the Statistical Analysis

Variable	Abbreviation	Description
Final Rank	Rank	Final rank in the free skating segment
Total Segment Score	TSS	Total Segment Score in the free skating segment
Base Value	BV	Sum of the base values of all technical elements
Technical Element Score	TES	Total score for technical elements
Program Component Score	PCS	Total score for program components
Grade of Execution	GOE	Sum of the GOE values awarded for all technical elements
Levels	Levels	Levels assigned to spins and step sequences
Element Execution Errors	–	Technical calls recorded for jump and spin execution (q, <, <<, !, e, and V)
Deductions	Deductions	Falls (F), falls outside technical elements, and other deductions

Statistical Analysis

Statistical analyses were performed using the Jamovi statistical software, version 2.6.26.0. Descriptive statistics were calculated for all study variables, including the mean, standard deviation (*SD*), median, minimum, and maximum values.

The normality of continuous variables was assessed using the Shapiro–Wilk test, complemented by visual inspection of Q–Q plots and histograms. Because most variables did not follow a normal distribution, associations between the study variables and the Total Segment Score (TSS) were examined using Spearman's rank correlation coefficient. To identify the independent technical factors associated with competitive performance, multiple linear regression analysis was performed with the Total Segment Score (TSS**)** as the dependent variable. The initial model included all technical performance indicators. After assessment of statistical significance and evaluation of multicollinearity using the variance inflation factor (VIF) and tolerance, the final regression model retained only significant predictors. Statistical significance was set at $p < 0.05$.

Results

Sample Characteristics and Descriptive Statistics

Descriptive statistics were calculated to summarize the characteristics of the study sample. For each variable, the mean, standard deviation (*SD*), median, minimum, and maximum values were computed and are presented in Table 2. The descriptive analysis revealed substantial variability in the technical performance indicators and the Total Segment Score (TSS), reflecting the differences in competitive level among the elite skaters. The mean Total Segment Score (TSS) was 162.0 ± 22.5 points, ranging from 119.0 to 228.0 points. The corresponding mean Total Element Score (TES) and Total Program Component Score (PCS) were 83.0 ± 15.6 and 79.2 ± 8.2 points, respectively.

Table 2. Descriptive Statistics for the Variables Included in the Statistical Analysis

Variable	Mean	*SD*	Median	Min	Max
Total Segment Score (TSS)	162.000	22.500	160.00	119.00	228.00
Total Element Score (TES)	83.000	15.600	80.60	52.30	137.00
Total Program Component Score (PCS)	79.200	8.240	77.80	61.80	96.60
Base Value (BV)	76.800	9.750	74.70	60.90	110.00
Total Grade of Execution (GOE)	6.260	8.440	6.02	-11.70	27.40
Quadruple jumps attempted	1.900	1.500	2.00	0.00	6.00
Clean quadruple jumps	1.180	1.230	1.00	0.00	6.00
Triple jumps attempted	6.140	1.450	6.00	2.00	8.00
Clean triple jumps	4.980	1.720	5.00	0.00	8.00
Clean double jumps	1.840	1.060	2.00	0.00	5.00
Popped jumps	0.198	0.450	0.00	0.00	2.00
Quarter calls (q)	0.583	0.804	0.00	0.00	3.00
Under-rotated jumps (<)	0.354	0.711	0.00	0.00	4.00
Downgraded jumps (<<)	0.073	0.261	0.00	0.00	1.00
Unclear edge calls (!)	0.375	0.653	0.00	0.00	3.00
Wrong edge take-offs (e)	0.031	0.175	0.00	0.00	1.00
Mean spin level	3.640	0.394	3.67	2.00	4.00
Step sequence level	3.160	0.730	3.00	1.00	4.00
Falls (F)	0.448	0.613	0.00	0.00	2.00
Falls outside elements	0.010	0.102	0.00	0.00	1.00
Other deductions	0.031	0.227	0.00	0.00	2.00

Correlation Analysis

The relationships between the Total Segment Score (TSS) and the analyzed variables were examined using Spearman's rank correlation coefficient. The results are presented in Table 3.

Table 3. Spearman Correlations Between Total Segment Score (TSS) and Performance Variables

Variable	Spearman's ρ	Variable	Spearman's ρ
Technical content		**Technical Errors in Jump Elements**	
Base Value	0.753^{***}	Popped jumps	-0.240^{*}
Quadruple jumps attempted	0.435^{***}	Quarter calls (q)	-0.134 (ns)
Triple jumps attempted	-0.126 (ns)	Under-rotated jumps (<)	-0.199 (ns)
Execution quality		Downgraded jumps (<<)	-0.197 (ns)
Total GOE	0.836^{***}	Unclear edge calls (!)	-0.303^{**}
Clean quadruple jumps	0.587^{***}	Wrong edge take-offs (e)	0.134 (ns)
Clean triple jumps	0.289^{***}	**Deductions**	
Clean double jumps	-0.420^{***}	Falls	-0.334^{***}
Levels		Falls outside elements	-0.068 (ns)
Mean spin level	0.541^{***}	Other deductions	0.172 (ns)
Spin V calls	-0.365^{***}		
Step sequence level	0.445^{***}		

Note. *ns*, not significant; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

The correlation analysis revealed statistically significant positive associations between the Total Segment Score (TSS) and variables reflecting the program's technical content and execution quality. The strongest positive correlations were observed for Base Value (BV) ($\rho = 0.753$, $p < 0.001$), Total Grade of Execution (GOE) ($\rho = 0.836$, $p < 0.001$), the number of clean quadruple jumps ($\rho = 0.587$, $p < 0.001$), mean spin level ($\rho = 0.541$, $p < 0.001$), and step sequence level ($\rho = 0.445$, $p < 0.001$). A weaker, but still statistically significant, positive correlation was also found for the number of clean triple jumps ($\rho = 0.289$, $p < 0.01$).

Statistically significant negative correlations with the Total Segment Score (TSS) were observed for the number of clean double jumps ($\rho = –0.420$, $p < 0.001$), the number of popped jumps ($\rho = –0.240$, $p < 0.05$), unclear edge calls (!) ($\rho = –0.303$, $p < 0.01$), spin V calls ($\rho = –0.365$, $p < 0.001$), and the total number of falls ($\rho = –0.334$, $p < 0.001$). No statistically significant correlations were found between the Total Segment Score (TSS) and the total number of attempted triple jumps, quarter calls (q), under-rotated jumps (<), downgraded jumps (<<), falls outside elements, or other deductions.

Multiple Linear Regression Analysis

To identify the independent factors associated with the Total Segment Score (TSS), a multiple linear regression analysis was performed. The initial model included all analyzed technical variables, and a final model was then constructed containing only those variables that remained significant independent predictors of the Total Segment Score (TSS). The results of the final regression model are presented in Table 4. The standardized regression coefficients of the final model are presented in Figure 1.

Table 4. Final multiple linear regression model predicting the Total Segment Score (TSS)

Independent predictor	*β*	B	SE	*t*	*p*	VIF	Tolerance
Clean quadruple jumps	0.682	12.48	0.925	13.49	< 0.001	1.08	0.922
Clean triple jumps	0.232	3.05	0.709	4.30	< 0.001	1.24	0.806
Mean spin level	0.218	12.45	3.289	3.79	< 0.001	1.40	0.713
Step sequence level	0.219	6.75	1.705	3.96	< 0.001	1.30	0.771
Falls	–0.148	–5.45	1.985	–2.75	0.007	1.24	0.806

Note. *Model fit: $R^2 = 0.788$; Adjusted $R^2 = 0.776$; N = 96. β, standardized regression coefficient; B, unstandardized regression coefficient; SE, standard error; VIF, variance inflation factor*

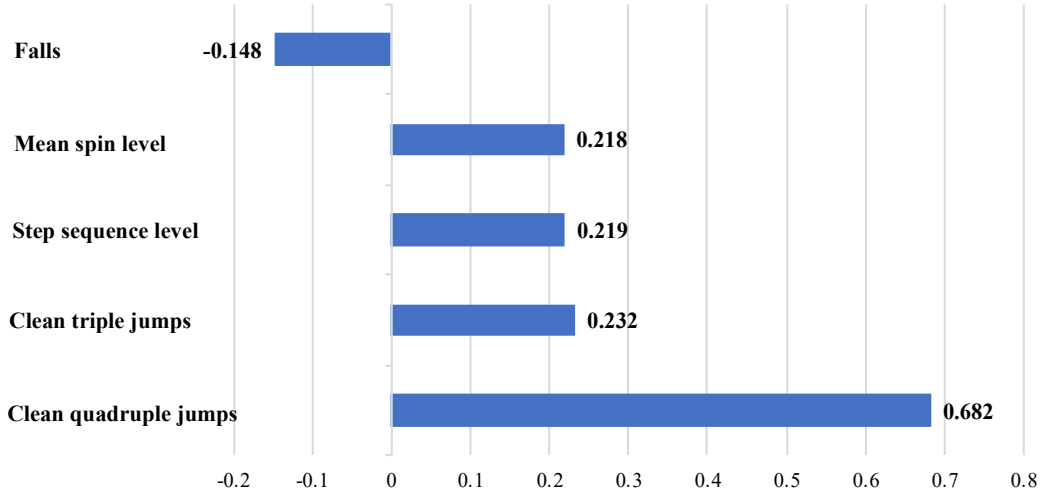

Fig. 1. Standardized regression coefficients (β) of the final regression model predicting Total Segment Score (TSS).

The final regression model explained 78.8% of the variance in the Total Segment Score (TSS) ($R^2 = 0.788$; Adjusted $R^2 = 0.776$). The number of clean quadruple jumps, the number of clean triple jumps, mean spin level, step sequence level, and the number of falls emerged as independent predictors of the Total Segment Score (TSS). The number of clean quadruple jumps showed the strongest independent association with the Total Segment Score ($\beta = 0.682$, $p < 0.001$). Comparable independent effects were observed for the number of clean triple jumps ($\beta = 0.232$, $p < 0.001$), step sequence level ($\beta = 0.219$, $p < 0.001$), and mean spin level ($\beta = 0.218$, $p < 0.001$). The number of falls was the only independent predictor negatively associated with the Total Segment Score ($\beta = –0.148$, $p = 0.007$).

Assessment of multicollinearity revealed no evidence of collinearity among the predictors, with all variance inflation factor (VIF) values below 2.0, confirming the stability of the regression model.

Discussion

The findings of the present study indicate that the number of clean quadruple jumps, the number of clean triple jumps, mean spin level, step sequence level, and the number of falls represent independent predictors of the Total Segment Score (TSS) in elite men's figure skating. Among these variables, the number of clean quadruple jumps exhibited the strongest independent association with the Total Segment Score, highlighting the importance of combining great technical difficulty with high-quality execution in achieving success at the highest level of international competition.

Previous studies have also highlighted the central role of cleanly executed quadruple jumps in elite men's figure skating. Rauer et al. (2022) reported a progressive increase in the number of quadruple jumps performed at the European and World Figure Skating Championships. Similarly, an analysis of Olympic women's singles between 2006 and 2022 demonstrated the increasing importance of technical difficulty and execution quality in competitive performance (Byun et al., 2026). Comparable conclusions were reached by Sezganov and Eryomina (2023), who emphasized that multi-rotational jumps are a primary means of enhancing competitive performance.

The biomechanical mechanisms underlying this relationship have been well documented in the literature. King et al. (1994, 2004) and King (2005) demonstrated that successful execution of multi-rotational jumps requires an optimal combination of high take-off velocity, sufficient flight time, high angular velocity, and a low moment of inertia. Achieving these conditions depends on the skater's ability to generate sufficient jump height during take-off. Podolsky et al. (1990) found that jump height is closely associated with knee extensor strength and upper-body musculature. In contrast, Lockwood et al. (2006) showed that successful landings depend not only on jump height but also on body stability and rotational control during flight. Hirosawa et al. (2022) further demonstrated that higher GOE values are associated with favorable kinematic characteristics, including jump height, although this relationship weakens in the presence of technical errors. More recently, Koga et al. (2025) reported significant biomechanical differences in lower-limb movement patterns between jumps with different numbers of rotations in young figure skaters, providing further evidence that biomechanical characteristics contribute to the successful execution of increasingly complex jumps.

These findings help explain why, in the present study, the number of clean quadruple jumps, rather than the total number of attempted quadruple jumps, emerged as the strongest independent predictor of the Total Segment Score (TSS). This suggests that competitive advantage in elite men's figure skating depends not only on incorporating elements with high Base Value (BV), but also on the ability to execute them consistently and with high precision while minimizing technical errors.

Another independent predictor of the Total Segment Score (TSS) was the number of clean triple jumps. Although its contribution was smaller than that of clean quadruple jumps, its statistical significance indicates that success in elite men's figure skating depends not only on the execution of the most technically demanding elements but also on the consistent execution of the program's overall technical content. Current trends in international figure skating likewise indicate that high scores are achieved through an optimal balance between technical difficulty and execution quality (Cheng & Gonzalez, 2022; Byun et al., 2026). Similar conclusions were reached by Kitaeva (2023), who demonstrated that increases in the technical value of skating programs are accompanied by higher Total Segment Scores, and that competitiveness at the elite level depends on the effective integration of technical difficulty and execution quality. In contrast, the present study found no statistically significant association between the number of under-rotated jumps (<) and the Total Segment Score, suggesting that, at the World Championship level, isolated errors of this type may be offset by the overall technical value and execution quality of the program. Compared with jumps, spins and step sequences have received considerably less attention in the literature. Nevertheless, the present study identified both variables as independent predictors of the Total Segment Score (TSS), emphasizing their importance for performance in elite men's figure skating.

These observations indicate that success in modern men's figure skating is determined not only by the execution of multi-rotational jumps but also by the quality of all technical elements performed throughout the program. This highlights the importance of comprehensive technical preparation, in which spins and the step sequence make a substantial contribution to competitive performance at the elite level. From a practical perspective, these elements should not be regarded as secondary in the training of elite skaters. Although their Base Values are considerably lower than those of quadruple jumps, achieving the highest possible levels and executing them with high quality make a meaningful contribution to the Total Segment Score (TSS).

The present results indicate that the number of falls is an independent negative predictor of the Total Segment Score (TSS). This finding is consistent with the scoring principles of the current ISU Judging System, under which falls have a cumulative negative impact on performance. According to ISU regulations, a fall results not only in a direct deduction but also in a substantial reduction in the GOE awarded for the affected element. Consequently, the impact of a fall extends beyond the deduction itself, leading simultaneously to a loss of technical points and a lower GOE. Together with the strong influence of cleanly executed triple and quadruple jumps, these results indicate that competitiveness in modern men's figure skating is determined not only by the technical difficulty of the program but also by the ability to perform technical elements consistently and with high quality under competitive conditions.

Competitive success in elite men's figure skating is determined by the complex interaction of technical difficulty, execution quality, and performance consistency. Although cleanly executed quadruple jumps make the greatest contribution to the Total Segment Score (TSS), clean triple jumps, mean spin level, step sequence level, and the absence of falls also play significant roles. The findings obtained indicate that success at the World Championship level depends not on a single technical element, but on the athletes' ability to maintain consistently high execution quality throughout the entire program.

A major strength of this study is the methodological homogeneity of the dataset. By limiting the sample strictly to the 2023–2026 championships, the confounding effects of the pre-2022 ISU judging system were avoided, ensuring that all 96 performances were evaluated under the identical three-component PCS structure.

Conclusion

The analysis of 96 free skating performances from 54 elite skaters competing at the ISU World Figure Skating Championships between 2023 and 2026 allows several conclusions to be drawn.

The number of clean quadruple jumps emerged as the strongest independent predictor of the Total Segment Score (TSS). In addition, the number of clean triple jumps, mean spin level, step sequence level, and the number of falls were identified as significant independent predictors.

The findings demonstrate that competitive success in elite men's figure skating depends not only on the technical difficulty of the program but also on the ability to execute technical elements consistently and with high quality throughout the program. These results emphasize the importance of a balanced training approach that optimizes all technical elements rather than focusing exclusively on increasing jump difficulty.

The present study contributes to a better understanding of the factors associated with competitive success in elite men's figure skating and provides practical implications for coaches and athletes in planning training and designing competitive programs. It also provides a foundation for future research integrating competition statistics with biomechanical, physiological, and training-related variables.

In practical terms, these findings suggest that training and competitive preparation should not focus exclusively on increasing technical difficulty. The strong independent contribution of clean quadruple and triple jumps indicates that the ability to execute difficult elements successfully is more important than simply attempting a greater number of high-value elements. At the same time, the independent contributions of mean spin level and step sequence level demonstrate that these components should be integrated into a comprehensive preparation strategy. The negative association of falls with the Total Segment Score further highlights the importance of execution consistency and error prevention. For coaches, these findings support a balanced approach that combines technical difficulty, execution quality, consistency, and the effective development of all technical elements within the program.

More broadly, this study contributes to the understanding of competitive success in elite men's figure skating. The findings demonstrate that performance is determined by the combined influence of technical difficulty, execution quality, and consistency rather than by a single technical characteristic. The use of four consecutive World Championships and the integration of correlation and multiple regression analyses provide a more comprehensive view of the independent contribution of individual technical indicators. Future research should extend this approach by combining official competition data with biomechanical, physiological, anthropometric, and training-related variables, which may provide a more complete explanation of the factors underlying elite competitive performance.

Limitations

The findings obtained in this study should be interpreted in light of several limitations. First, the sample comprised 96 free skating performances from the ISU World Figure Skating Championships held between 2023 and 2026, corresponding to the 2022–2026 Olympic cycle. Consequently, the findings primarily apply to elite skaters competing at the World Championship level and cannot be directly generalized to other competitions or athlete populations. Second, the analysis was based exclusively on official ISU competition protocols and did not include biomechanical, physiological, or anthropometric variables, which may also influence competitive performance. Third, the study did not account for factors such as training characteristics, competitive experience, age, or other individual athlete attributes that may affect the consistency of technical execution. Future research should integrate competition statistics with biomechanical, physical, and training-related variables to develop a more comprehensive model of the factors determining competitive success in elite men's figure skating.

Conflict of Interest

No potential conflict of interest was reported by the authors.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist in improving its language, grammar, and clarity. After using this tool, the authors reviewed and edited the text as needed and take full responsibility for the content of the publication.

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