FACTA UNIVERSITATIS
Series: **Teaching, Learning and Teacher Education** Vol. 9, N°1, 2025, pp. 91 -100
https://doi.org/10.22190/FUTLTE250507011I

Original research paper

THE IMPACT OF DIVERSE PREDICTORS ON SHOW JUMPING COMPETITION OUTCOMES

UDC 798.26:796.012.4
796.058.4
796.012.1

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Abstract. *Even though its role in the development of equestrian sports has been confirmed, a small number of authors have conducted a thematic analyses of the interaction between errors and sports performance in the show jumping discipline. This may indicate that performance analysis is still insufficiently emphasized in equestrian sports, particularly in relation to sports performance. The aim of this study was to identify types of errors as predictors of total penalty points in a competition and to determine their predictive capacity as components of performance. A total of 7,285 jumping actions were analyzed during the "Balkan Championship 2022" across 512 starts. The identified errors (independent variables – predictors) included: obstacle knockdown (OP), stepping into water (SV), first refusal (PN), second refusal (DN), first closed circle (PZK), second closed circle (DZK), fall of the rider and/or horse (PJ/K), exceeding the allowed time (PDV), exceeding the maximum allowed time (PMDV), and jumping the wrong obstacle (PSP). Their impact was assessed on the total penalty points (UKP) (dependent variable). The data obtained were processed using the SPSS 19 statistical package. Descriptive statistical parameters were calculated, followed by Pearson's correlation analysis to determine the strength and direction of existing correlations. Multiple regression analysis was then applied to assess the influence of the independent variables (errors) on the dependent variable (UKP). The results of this model indicate that the cumulative effect of the predictors significantly (Sig=0.000[a]) explains 88% of the total variance in UKP. With statistical significance confirmed for all independent variables (Sig≤0.027), their individual positive correlations with the dependent variable ranged from r=0.85 to r=0.774. Individually, all predictors exerted a differentiated yet statistically significant influence, with statistical significance (Sig=0.000), with effects ranging from minimal [PDV (t=3.708; Sig=0.000; β=0.063; 0.34%)] to maximal [DN (t=19.889; Sig=0.000; β=0.424; 9.54%)]. It*

Received May 7, 2025 / Revised June 5, 2025 / Accepted July 4, 2025
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can be concluded that all predictors, when viewed individually, are significant, while they simultaneously exert a cumulative significant influence on UKP. Furthermore, each predictor individually exerts a statistically significant predictive effect on UKP. This analysis provides valuable data for all stakeholders and may support the development and implementation of more effective competition strategies aimed at improving performance.

Key words: *equestrian sport, show jumping, errors, faults, prediction.*

1. INTRODUCTION

Morphological diversity and simultaneous harmony are what make show jumping one of the most popular equestrian Olympic disciplines (Clayton & Hobbs, 2017). Through an intrinsic bidirectional motivation and a harmonious communicative channel established within the dyad, and while ensuring all aspects of the horse's welfare (Christensen, Jensen & von Borstel, 2024; O'Connell, Dyson, McLean & McGreevy, 2025), the rider and horse are expected to complete their competitive round with as few penalty points as possible (Aegerter et al., 2020). Equestrian sport is the only Olympic discipline not organized around gender segregation (Ilić, Stojiljković & Stanković, 2024). Although horses are animals with considerable athletic potential, they are not naturally self-motivated to jump over obstacles (Górecka-Bruzda, 2013), which can lead to acute negative stress during competitive jumping (Bartolomé & Cockram, 2016; Gregić, Bobić, Baban, Bunevski & Gantner, 2020). Stressors stemming from obstacle design, course layout, and external environmental conditions may result in errors during jump performance (Borstel, Visser & Hall, 2017; Rudmieze & Fernate, 2023, July). In accordance with FEI rules, such errors contribute to the total number of penalty points awarded in a competition. These may include obstacle knockdowns, stepping into water, first and second refusal, first and second closed circle between two consecutive obstacles, fall of the rider and/or horse, exceeding the allowed time, exceeding the maximum allowed time, and jumping the wrong obstacle (FEI Jumping Rules, accessed March 10, 2025). As in other sports (Han, Geminiani & Micheli, 2018; Owens, Nacca, Harris & Feller, 2018; Rooney, Sarriegui & Heron, 2020; Paunović, Đorđević, Veličković, Đurović, Paunović & Veličković, 2024;) it is important to emphasize that certain errors or incidents may result in falls and injuries (Meyer et al., 2022). Regardless inter-actor dynamics within the dyad, it must be unequivocally stated that the responsibility for performance lies solely with the rider (Williams & Tabor, 2017), which can be enhanced through developing a refined "feel" for the horse (Clayton, MacKechnie-Guire & Hobbs, 2023; Stringer, Lewis & Davies, 2024).

In equestrian sports, as in other discliplines, performance analysis can contribute to identifying factors that enhance results. Although few studies have examined errors and performance in show jumping, some authors have presented data of a theoretical and practical value. Ničová & Bartošová (2022) analyzed errors and their related factors in 13 competitions of the Western European League 2017/2018, across both primary and jump-off courses. The analyzed error factors included obstacle type, rider experience, direction of approach, laterality effect, rider gender, and movement speed. The design and type of obstacle were found to be associated with performance, whereas rider experience, movement speed, laterality, rider gender, and direction of approach were not considered significant contributors to errors. Ilić & Stanković (2023) reported a significant difference in performance across different obstacle heights. Similarly, Williams, J. (2013) and Whitaker et al. (2012) analyzed performance differences between male and female riders and concluded that gender does not

significantly affect efficiency. Ilić, Stanković & Stojiljković (2024) also found no significant gender-related differences in the number of errors. It is well established that each sport develops specific motor skills (Moody, Naclerio & Green, 2013; Nazario & Vieira, 2014; Szabo, 2021; Veljković, Stanković, & Božić, 2022; Miletić, Aksović, Bjelica, Veličković & Ilić, 2022; Nejić, Nejić, Stojiljković & Okičić, 2023). While horseback riding in youth contributes to the development of motor skills essential for equestrian sports (Ilić, Stojiljković & Stanković, 2024) Rudmieze & Fernate (2023, July) analyzed performance across different age groups and concluded that no single factor consistently serves as a stable predictor of expected performance. Stachurska, Pięta & Nesteruk (2002) found that the type, height, color, and arrangement of obstacles significantly influenced the number of errors. Marlin & Williams (2020) noted that during the 2017 International Nations Cup jump-off, the most common errors were obstacle knockdowns (5.5%), exceeding the allowed time (0.8%), water jumps errors (0.3%), and refusals (0.2%).

The aim of this study is to analyze the relationship between errors and the total number of penalty points awarded in the main round of the "Balkan Equestrian Championship 2022" in show jumping. The analyzed indicators include specific types of errors and the total number of penalty points assigned in the main round of the competition.

METHODS

The necessary data were collected at the "Balkan Equestrian Championship 2022" (hereinafter referred to as BEC 2022) in show jumping (BECh-S – Balkan Equestrian Championship – Jumping), held in Romania from September 7 to 11, 2022. A total of 7,285 jumping actions (N=7285) were recorded across 512 starts at BEC 2022. Selected performance indicators were registered for each jumping action. The nominated performance indicators included: obstacle knockdown (OP), stepping in water or leaving a hoof print on the rail along the edge of the large water jump on the landing side (SV), first refusal (PN), second refusal (DN), first closed circle (PZK) and second closed circle (DZK) between two consecutive obstacles, fall of the rider and/or horse (PJ/K), exceeding the allowed time (PDV), exceeding the maximum allowed time (PMDV), jumping the wrong obstacle (PSP), and the total number of penalty points awarded in the main round of the competition (UKP).

The required data for analysis were obtained through notational analysis during the course of the competition. Performance indicators for each competitor's performance were recorded on the judges' sheets and cross-verified with the data displayed on a video screen. A video recording of each performance was made using a digital video camera recorder ("SONY, 40x Optical Zoom, 30 GB Up to 20 Hrs. Recording") with a focus on documenting the performance indicators during jumping actions. The competitors' results were then compared with the official results, which were compiled by the event organizer using an error detection and scoring system ("Tag Heuer CP545 HL615 – 2 receiver" and "ALGE/Timing/Wireless Timing Network"). Permission for data collection was granted by BEC 2022 organizer.

The descriptive statistical parameters calculated included the mean and standard deviation, while the relationship between situational efficiency parameters and sports performance was assessed using multiple regression analysis and Pearson's correlation coefficient. A significance level of $p < 0.05$ was applied to determine statistical significance. Data processing was conducted using the SPSS 19 statistical software package.

RESULTS

The results indicate that the average total number of penalty points (UKP) in the competition was 9.931±12.084. The mean values show that the obstacle knockdown (OP) had a value of 1.23±1.244, while the PMDV error did not occur at all (0.00±0.00). Pearson's correlation coefficient (r) indicated the highest correlation between UKP and the first refusal (PN) (r=0.774; Sig=0.000), followed by the second refusal (DN) (r=0.668; Sig=0.000), the fall of the rider and/or horse (PJ/K) (r=0.424; Sig=0.000), the obstacle knockdown (OP) (r=0.363; Sig=0.000), the first and second closed circle (PZK and DZK) (r=0.143; Sig=0.001), exceeding the allowed time (PDV) (r=0.101; Sig=0.011), DN (r=0.668; Sig=0.000), and jumping the wrong obstacle (PSP) (r=0.099; Sig=0.012). Since there were no recorded instances of PMDV at the BEC 2022, no correlation could be established for that parameter. The results show that all observed parameters are positively correlated with the total number of penalty points in the competition, ranging from very weak (r=0.099) to very strong (r=0.774), with statistical significance.

Table 1 The descriptive statistics of the parameters, Pearson's correlation

	N	Mean	Std. Deviation	UKP	
				r	Sig
UKP	512	9.931	12.084	1.000	
OP	512	1.23	1.244	0.363	0.000
SV	512	0.15	0.356	0.085	0.027
PN	512	0.12	0.329	0.774	0.000
DN	512	0.05	0.220	0.668	0.000
PZK	512	0.00	0.44	0.143	0.001
DZK	512	0.00	0.44	0.143	0.001
PJ/K	512	0.02	0.145	0.424	0.000
PDV	512	0.15	0.354	0.101	0.011
PMDV	512	0.00	0.000	/	/
PSP	512	0.00	0.44	0.099	0.012

Legend: N – number of starts, Mean – mean value, Std. Deviation – standard deviation, UKP – the total number of penalty points, OP – obstacle knockdown, SV – stepping in water at the large water jump, PN – first disobedience, DN – second disobedience, PZK –first closed circle, DZK – second closed circle, PJ/K – fall of the rider and/or horse, PDV – exceeding the allowed time, PMDV – exceeding the maximum allowed time, PSP – incorrectly jumped obstacle.

In the absence of multicollinearity (Tol>0.10; VIF<10), the correlation coefficient results presented in Table 2 indicate a significantly strong relationship between the analyzed predictors and the total penalty points (UKP) in the competition ($R=0.937^a$). the coefficient of determination ($R^2=0.879$) shows that the predictors in this model explain 88% of the total variance in the dependent variable (UKP). It can be concluded that the predictors have a very strong effect on UKP. The adjusted coefficient of determination (Adjusted $R^2=0.877$) suggests that the inclusion of an additional predictor would not improve the model. The statistical significance of the model (F=456.326; $Sig=0.000^a$) confirms the influence of the predictors on UKP, indicating their relevance in explaining it. The obstacle knockdown (OP) is a statistically significant predictor (t=23.196; Sig=0.000) with a moderate effect ($\beta=0.363$), uniquely accounting for 12.96% of the total variance in UKP. Stepping in water (SV) is also statistically significant predictor (t=7.331; Sig=0.000), though it has a weak

effect (β=0.116), accounting for 1.3% of the variance. The first refusal (PN) shows statistical significance (t=16.723; Sig=0.000) with a moderate effect (β=0.395), uniquely explaining 6.71% of the variance. The second refusal (DN) is a significant predictor as well (t=19.889; Sig=0.000) with a moderate effect (β=0.424), contributing a 9.55% of the total variance. The second closed circle (DZK) is a significant predictor as well (t=11.268; Sig=0.000) with a weak effect (β=0.175), explaining 3.06% of the variance. The fall of the rider and/or horse (PJ/K) is also a significant predictor (t=14.427; Sig=0.000) with a weak effect (β=0.257), accounting for 5.02% of the variance. Exceeding the allowed time (PDV) has a statistically significant, but extremely weak effect (t=3.708; Sig=0.000; β=0.063), explaining just 0.34% of the variance. Jumping the wrong obstacle (PSP) is a statistically significant predictor (t=5.113; Sig=0.000) with a very weak effect (β=0.080), explaining 0.62% of the variance in UKP.

Table 2 Coefficients

M	Unstandardized Coefficients		Standardized Coefficients	t	Sig	Correlations			Collinearity Stat.		Model quality parameters
	B	Std. Error	Beta			Zero-order	Partial	Part	Tol.	VIF	
1(C)	1.130	0.289		3.905	0.000						
OP	3.530	0.152	0.363	23.196	0.000	0.363	0.719	0.360	0.981	1.019	R=0.937[a]
SV	3.943	0.538	0.116	7.331	0.000	0.085	0.311	0.114	0.960	1.042	R^2=0.879
PN	14.513	0.868	0.395	16.723	0.000	0.774	0.598	0.259	0.432	2.316	Adj
DN	23.305	1.172	0.424	19.889	0.000	0.668	0.663	0.309	0.530	1.886	R^2=0.877
DZK	47.870	4.248	0.175	11.268	0.000	0.143	0.449	0.175	0.997	1.003	F=456.326
PJ/K	21.365	1.481	0.257	14.427	0.000	0.424	0.541	0.224	0.761	1.314	Sig=0.000[a]
PDV	2.152	0.580	0.063	3.708	0.000	0.101	0.163	0.058	0.833	1.201	
PSP	21.809	4.266	0.080	5.113	0.000	0.099	0.222	0.079	0.989	1.011	

a. Predictors: PSP – incorrectly jumped obstacle, DZK – second closed circle, PJ/K – fall of the rider and/or horse, PDV – exceeding the allowed time, OP – obstacle knockdown, DN – second disobedience, SV – stepping in water at the large water jump, PN – first disobedience.
b. Dependent variable: sum of penalty points during the competition (the main round).

Legend: 1(C) – Constanta – constant, B – unstandardized coefficient, Std. Error – standard error, Beta – standardized coefficient, t – statistical value for testing the significance of the regression model coefficient (t-statistics), Sig – confidence level, Zero-order – Zero-order Correlation), Partial – Partial Correlation, Part – Part correlation, Collinearity Stat. – Collinearity Statistics, Tol. –Tolerance, VIF – Variance Inflation Factor, R – correlation coefficient, R^2 – coefficient of determination, Adjusted R^2 – adjusted coefficient of determination, F (test) – ratio between regression and residual variance, Sig – significance level, OP – obstacle knockdown, SV – stepping in water at the large water jump, PN – first disobedience, DN – second disobedience, DZK – second closed circle, PJ/K – fall of the rider and/or horse, PDV – exceeding the allowed time, PSP – incorrectly jumped obstacle.

DISCUSSION

Unlike other sports, where performance analysis has long been established as a method for monitoring success and identifying the factors that influence final outcomes (Williams, 2013), in equestrian sports, performance analysis focusing on errors and total penalty points in competition has only recently been implemented. In our study, 7,285 jumping actions were recorded, with a total error rate of 12.12%, broken down as follows: 8.63% obstacle knockdowns, 1.04% stepping in water, 0.86% first refusals, 0.36% second refusals, 0.15%

falls of the rider and/or horse, 0.01% first closed circles, 0.01% second closed circles, 1.03% exceeding the allowed time, and 0.01% jumping the wrong obstacle. A lower overall error rate of 7.85% (knockdowns and refusals) was reported by Ničová & Bartošová (2022) in their analysis of 9,114 jumping actions at heights of 140–160 cm during the Western European League. Similarly, Marlin & Williams (2020) reported a total error rate of 6.4% in a jump-off competition at the 2017 International Nations Cup, consisting of 5.5% obstacle knockdowns, 0.8% exceeding the allowed time, 0.3% water jumps errors, 0.2% refusals. At regional competitions, analyzing 5,639 jumping actions at 140 cm, Stachurska, Pięta & Nesteruk (2002) reported error rate variability ranging from 11.22% to 18.69%.

The findings (Table 1) show a significant positive correlation between errors and total penalty points in the competition ($r \geq 0.085$; $Sig \geq 0.027$). A strong relationship ($R^2=0.879$), with statistical significance, is evident between the selected predictors and the total number of penalty points in the main round of the competition, where the analyzed errors explain 88% of the total variance in penalty points (Table 2).

The first and second instances of disobedience at BEC 2022 had a statistically significant and strong impact and, compared to other errors, showed the highest correlation with the total number of penalty points in the competition (Table 1). Individually, they demonstrated the strongest predictive power for penalty points [First Disobedience (PN) ($\beta=0.395$) and Second Disobedience (DN) ($\beta=0.424$)], uniquely explaining 6.71% and 9.55% of the total variance in penalty points, respectively (Table 2). According to FEI rules, the first instance of disobedience limits the possibility of repeating the error, while the second results in automatic disqualification from the competition, adding 20 penalty points to the worst result in the event. Although relatively rare, the etiology of disobedience may indicate insufficient coordination of horse-rider pairs when facing obstacles of different designs (Christensen, Ahrendt, Malmkvist & Nicol, 2021), poor riding technique (Gjulem, 2023), inadequate movements by the horse or rider (Clayton et al., 2023), or overly complex course requirements (Górecka-Bruzda et al., 2013). Obstacle knockdown was also a significant predictor, with a moderate impact on penalty points, explaining 12.96% of the totalvariance in the penalty points in the competition (Table 2). While both riders and horses are generally prepared for jumping obstacles, clearing them without knockdowns can still pose a challenge. The design, dimensions, and positioning of obstacles may hinder performance and lead to knockdowns (Stachurska et al., 2002; Marlin & Williams, 2020; Ničová & Bartošová, 2022). Falls of the rider and/or horse, though statistically significant, had a weaker impact, accounting for 5.02% of the total variance. Despite being rare, such incidents may result from stimuli that trigger acute stress responses in horses, leading to abrupt behavioral changes (Murray, Singer, Morgan, Proudman & French, 2006; McGreevy & McLean, 2007; McGreevy, Oddie, Burton & McLean, 2009). These reactions may generate strong inertial forces (Havlik, 2010), ultimately causing a fall. Stepping in water and the second closed circle were also significant predictors. Thought they had weaker effects on penalty points, accounting for 1.3% and 3.06% of the total variance in penalty points, respectively. Complex kinematic conditions, the disturbing effect of water, and difficulty positioning the horse for an optimal takeoff can lead to refusals at water jumps (Stachurska et al., 2010; Stinner, 2013; Clayton et al., 2021; Lorin & Westman, 2020). Additionally, cognitive lapses under competitive pressure can cause riders to forget the course sequence, resulting in errors such as performing a second closed circle between jumps (Polackova, 2018; Iungano et al., 2019; Schütz et al., 2023). Exceeding the allowed time and jumping the wrong obstacle were also statistically significant predictors but had an extremely weak impacts on penalty points,

explaining only 0.34% and 0.62% of the total variance in penalty points, respectively. Poor riding technique and competition-inducted anxiety can impair a rider's cognitive, emotional, and behavioral functioning, potentially leading to such errors (Williams & Tabor, 2017; Clayton et al., 2023; Stringer et al., 2024; Adi et al., 2024).

The limitation of this study lies in the absence of an analysis of the training levels of the rider and the horse, as well as their behavior within the actor relationship of the dyad, including the biomechanics of movement in different temporal and positional contexts when errors occur. Additionally, the analysis was conducted at the level of a regional championship competition. Missing data related to the analyzed errors should be addressed in future research. Despite these limitations, the collected data and the identification of errors, with a focus on their predictive impact on total penalty points, can assist trainers and riders in developing training strategies, refining competitve performance, and implementing appropriate tactics, particularly those aimed ateliminating the most influential predictive errors.

CONCLUSION

This paper presents a final model demonstrating that the total number of penalty points during the main part of the competition is significantly determined and explained (88%) by the cumulative predictive influence of errors. The study showed that all the analyzed errors (predictors – independent variables) in this model were individually and significantly identified in terms of their correlation, predictive power, and the percentage of the total variance in penalty points explained in the main competition (the dependent variable). The analysis of errors from BEC 2022 in this model indicated that each predictor possesses distinct predictive capacity, which can support the development of advanced training strategies and competitive approaches aimed at reducing penalty points and improving performance. This underscores the importance of strict adherence to the principles of equine welfare and well-being, ensuring the avoidance of unethical training practices, improper methods, and harmful competitive performances, as well as the prevention of psychological or physical distress or pain inflicted on horses. A limitation of this study lies in its inability to definitively detect and isolate intrinsic inter-actor dynamics within the dyad, its kinematics characteristics, and external factors such as course design and environmental conditions. Future research should aim to explore and verify the consistency of these findings obtained by incorporating a broader range of variables identified here as limitations. In the broader context of performance analysis application, this study contributes to achieving optimal competitive outcomes by highlighting the complex and multidisciplinary components of performance and their roles in execution. From both theoretical and practical perspectives, it offers valuable insights for trainers, riders, and course designers in identifying obstacles to achieving higher-level performance, with a focus on minimizing the occurrence of high-impact predictive errors.

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UTICAJ RAZLIČITIH FAKTORA PREDIKCIJE NA REZULTATE U DISCIPLINI PRESKAKANJA PREPONA

I pored toga što je uloga konjičkog sporta u njegovom razvoju potvrđena, mali broj autora je sproveo tematsku analizu interakcije između grešaka i sportske uspešnosti u disciplini preskakanja prepona, što može ukazivati na nedovoljnu zastupljenost analize performansi u konjičkom sportu, sa posebnim osvrtom na sportsku uspešnost. Cilj ove studije bio je da se identifikuju tipovi grešaka kao prediktori ukupnog broja kaznenih poena na takmičenju i da se utvrdi njihova prediktivna moć u okviru ukupne sportske performanse. Ukupno je analizirano 7.285 skokova tokom „Balkanskog prvenstva 2022“, u okviru 512 startova, pri čemu su analizirane greške (nezavisne varijable – prediktori) obuhvatile: rušenje prepreke (OP), gaženje vode (SV), prvo odbijanje (PN), drugo odbijanje (DN), prvi zatvoreni krug (PZK), drugi zatvoreni krug (DZK), pad jahača i/ili konja (PJ/K), prekoračenje dozvoljenog vremena (PDV), prekoračenje maksimalno dozvoljenog vremena (PMDV), kao i skakanje pogrešne prepreke (PSP), i njihov uticaj na ukupan broj kaznenih poena (UKP) (zavisna varijabla). Dobijeni podaci obrađeni su statističkim paketom SPSS 19. Izračunati su deskriptivni statistički parametri, zatim je sprovedena Pirsonova korelaciona analiza radi utvrđivanja postojanja međuzavisnosti, kao i višestruka regresiona analiza sa ciljem procene uticaja nezavisnih varijabli (grešaka) na zavisnu varijablu (UKP). Rezultati dobijeni ovim modelom ukazuju da kumulativni efekat prediktora statistički značajno (Sig=0.000ª) objašnjava 88% ukupne varijanse UKP. Sa potvrđenom značajnošću svih nezavisnih varijabli (Sig≤0.027), izračunate su njihove individualne pozitivne korelacije sa zavisnom varijablom, koje se kreću u rasponu od r=0.85 do r=0.774. Svi prediktori imaju individualni, diferencirani prediktivni uticaj, uz statističku značajnost (Sig=0.000), u rasponu od minimalnog efekta [PDV (t=3.708; Sig=0.000; β=0.063; 0.34%)] do maksimalnog efekta [DN (t=19.889; Sig=0.000; β=0.424; 9.54%)]. Može se zaključiti da su svi prediktori, posmatrani pojedinačno, statistički značajni, dok istovremeno ostvaruju i kumulativno značajan uticaj na UKP. Pored toga, svaki prediktor zasebno pokazuje statistički značajnu prediktivnu moć u odnosu na UKP. Ova analiza može pružiti korisne informacije svim akterima u cilju razvijanja i implementacije efikasnijih takmičarskih strategija usmerenih ka unapređenju sportske uspešnosti.

Ključne reči: *konjički sport, preskakanje prepona, greške, prestupi, predikcija.*