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THE STRUCTURE OF THE MAN AND WOMEN COMPETITION PERFORMANCE OF THE SECOND JUMP ON THE SMALL JUMPING HILL AT THE OLYMPIC GAMES, BEIJING 2022

STRUKTURA TEKMOVALNE USPEŠNOSTI SMUČARJEV SKAKALCEV IN SKAKALK DRUGEGA SKOKA NA MALI SKAKALNICI NA OLIMPIJSKIH IGRAH V BEIJINGU LETA 2022

ABSTRACT

The purpose of the research study was to determine the structure of the competitive performance variables of male and female ski jumpers who participated in the second series of the competition on the smaller HS106m ski jumping hill at the Beijing 2022 Winter Olympics. The dependent criterion variable was the length of the jump. The following independent variables were included: in-run velocity, flight velocity at a point 30 m after the end of the take-off table, velocity of movement of the jumper at landing, V-angle between the skis at a point 30 m after the end of the take-off table and wind speed. Descriptive statistics, correlation analysis, and factor analysis were used to analyze the data. Differences in the dependent criterion variable (jump length) were much higher in women (M = 85 m, SD = 8.3 m) than in men (M = 98 m, SD = 3.9 m). At a fairly similar in-run velocity, men achieved an average of 13 m longer final jump than women. A statistically significant correlation between jump length and wind speed was observed in males (r = .42). In females, the variables in-run velocity (r = .59) and landing speed (r = .59) were significantly corelated with jump length. The multiple correlation showed a much higher correlation of independent variables in women (Mult R = .78; Sig R = 0.00) than in men (Mult R = .54; Sig R = 0.23). The overall competitive performance factor for men and women was largely determined by the jump length and style scores variables. The wind speed factor was completely independent of the other independent variables. The research showed a significant difference in the average quality level of competitive performance in male and female category. In particular, women had a much higher variability in competitive performance than men. The results of the survey confirmed that for a top achievement, in addition to the length of the jump, the score for style is also important. Based on this important knowledge for practice, coaches should pay more attention to the development of the aesthetic component of ski jumping technique.

Keywords: Ski jumping, competitive performance, Winter Olympic games 2022

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IZVLEČEK

Namen raziskovalne študije je bil ugotoviti strukturo spremenljivk tekmovalne uspešnosti smučarjev skakalcev in smučark skakalk, ki so nastopili v drugi seriji tekmovanja na manjši skakalnici HS106m na zimskih olimpijskih igrah v Pekingu 2022. Odvisno kriterijsko spremenljivko je predstavljala dolžina skoka. Med neodvisne spremenljivke so bile uvrščene: zaletna hitrost, hitrost leta v točki 30 m za robom odskočišča, hitrost ob doskoku, kot med smučkama v točki 30 m za robom odskočišča in hitrost vetra. Za analizo podatkov je bila uporabljena opisna statistika, korelacijska analiza in faktorska analiza. Razlike pri odvisni kriterijski spremenljivki (dolžina skoka) so bile precej višje pri ženskah (M = 85 m, SD = 8,3 m) kot pri moških (M = 98 m, SD = 3,9 m). Pri podobni zaletni hitrosti so moški dosegli v povprečju 13 m daljši finalni skok kot ženske. Pri moških je bila ugotovljena statistično pomembna korelacija med dolžino skoka in hitrostjo vetra (r = 0,42). Pri ženskah sta bili z dolžino skoka značilno povezani spremenljivki zaletna hitrost (r = 0,59) in hitrost ob doskoku (r =0,59). Z multiplo korelacijo je bila ugotovljena precej višja povezanost neodvisnih spremenljivk pri ženskah (Mult R = 0,78; Sig R = 0,00) kot pri moških (Mult R = 0,54; Sig R = 0,23). Faktor tekmovalne uspešnosti sta tako pri moških kot pri ženskah v največji meri skupno determinirali spremenljivki dolžina skoka in stilne ocene. Faktor hitrosti vetra je bil neodvisen od ostalih neodvisnih spremenljivk. Raziskava je pokazala značilno razliko v povprečni kakovostni ravni tekmovalne uspešnosti v moški in ženski konkurenci. Še zlasti je bila pri ženskah prisotna precej višja variabilnost tekmovalne uspešnosti kot pri moških. Rezultati raziskave so potrdili, da je za vrhunski dosežek, poleg dolžine skoka pomembna tudi ocena za slog. Na osnovi tega pomembnega spoznanja za prakso, bi morali trenerji posvetiti več pozornosti razvoju estetske komponente tehnike smučarskega skoka.

Ključne besede: smučarski skoki, tekmovalna uspešnost, zimske olimpijske igre 2022

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INTRODUCTION

Ski jumping is a winter sport with a rich Olympic tradition, it started back in 1924 at the first Winter Olympic Games in Chamonix, France. The Olympic Games are among the most prestigious competitions in ski jumping. The competitive performance of ski jumpers is always influenced by many objective and subjective factors (Jošt, Čoh, Čuk & Vodičar, 2016). Their influence is complex and can manifest itself in a completely different way for each jump. A large number of factors that influence competitive performance are impossible to research in competitions. Some, however, can be studied when, of course, relevant data is available. Competitive performance in each series depends on the length of the jump and style ratings. There is generally a certain correlation between them. Jumpers with longer jump lengths also tend to receive more points. Landing and outrun scores are fairly independent from the length of the jumps.

Jump length generally depends on many factors (Müller, 2008). Above all, jumpers must have a refined jumping technique. This depends on the physical efficiency of the jumper, their morphological characteristics, and equipment (skis, boots, bindings, and jumping suit). Ski jumping technique can also be influenced by other factors (rain, snow, wind, and air temperature). In particular, the wind can have a strong influence on the performance of ski jumpers, and can also actually prevent the competition (Virmavirta & Kivekäs, 2012; Virmavirta & Kivekäs, 2022). Due to the wind, many competitions only had one series, and some were cancelled entirely. In the past, it sometimes significantly extended the length of time the competition lasted, which reduced its attractiveness to the audience. In 2010, the International Ski Federation started to regulate the effect of the wind on the length of the jump, and at the same time, it also introduced the possibility of changing the length of the start gate during each series. Wind compensation points were introduced – they depend on the speed and direction of the wind and the size of the hill. On larger hills, the number of points increases relative to the speed and direction of the wind. Tailwinds have a slightly stronger influence than headwinds. The majority of experts agree that the introduction of the wind regulation has resulted in a fairer evaluation of competitive performance. However, there is still a need to update the methods for measuring and evaluating the impact of wind (Virmavirta & Kivekäs, 2022).

The jump length can be significantly affected by in-run velocity. In the first in-run phase of a ski jump, the jumper must ensure the highest possible in-run velocity and optimize the take-off position for the start of the take-off. From a physical point of view, in-run velocity has a direct impact on jump length. The influence of in-run velocity on jump length has already been the subject of research by various authors. Vaverka (1987), using a sample of top competitors between 1973 to 1984, repeatedly found a statistically significant influence of the in-run velocity on the jump length of ski jumpers. The correlation between in-run velocity and jump length ranged from .35 to .48. A statistically significant impact of in-run velocity on jump length was also found in research conducted in 1983 and 1984 on a sample of the world's best jumpers (Jošt, 2009). In a large-scale experiment in late 2008 (Vodičar & Jošt, 2017) performed on a sample of 30 Slovenian jumpers performing seven series of jumps under similar conditions on the same HS100 m hill over a period of two hours, low and medium correlations were found between the in-run velocity and the length of the jumps (.28 and .49). The influence of in-run velocity on the length of jump is difficult to study nowadays, because the start gates, and thus the in-run velocity, can change during the series.

Researchers of ski jumping technique pay particular attention to the take-off and flight phases. During the take-off and flight phases, the jumper should optimally perform three movement tasks: 1. maintain the highest possible horizontal velocity of movement; 2. minimize the vertical velocity of movement; and 3. optimize take-off timing (Jošt & Vodičar, 2019). During the flight phase, the jumper must maintain as large a horizontal component of flight velocity as possible, while minimizing the vertical component of flight velocity. The flight performance of jumpers also depends on their weight (Oggiano & Saetran, 2008). To maintain the maximum possible horizontal flight velocity, the jumper must minimize the force of air resistance in the horizontal direction of flight. They achieve this by optimizing the aerodynamic layout of their body and skis. In the middle and final parts of the flight, the tendencies regarding the influence of the horizontal and vertical components of velocity on the length of jumps are quite similar.

During the competitions at the Winter Olympics in Beijing, flight velocity measurements were taken at a point 30 m after the end of the take-off table. The velocity of the jumper was also measured during landing. However, the flight velocity measurements did not provide information about the flight angle or about the horizontal and vertical components of the flight velocity. With the same flight velocity, the vector quantities of both components can vary significantly during the entire flight phase and, as a result, can have a fairly different contribution to the competitive performance of each jumper.

It is necessary to create an individual model of optimal ski jumping technique for each jumper (Jošt, Supej & Vodičar, 2022). The design of this model also includes the position of the skis during flight. The longitudinal angle between the skis and the horizontal axis should be minimal throughout the flight. In this way, the jumper minimizes air resistance in the horizontal direction of flight and at the same time maximizes the positive influence of the air resistance of the skis in the vertical direction of flight. The V-angle between the skis also plays a certain role. This should be somewhere between 25 and 40 degrees. This angle was measured at the Olympic Games' competitions in Beijing. Thus, it is possible to determine the strength of the correlation between this angle and competitive performance in the series. Hypothetically, it is difficult to expect a high correlation, because at the same V-angle between the skis, quite different longitudinal rotations of the skis can occur during the flight. Not knowing the angle of longitudinal rotation also reduces the value of knowing the influence of the V-angle during flight.

The purpose of this research study was to identify any relation of selected variables with competitive performance in two final smaller hill (HS106m) series at the Beijing 2022 Winter Olympic Games. This type of research is limited by the low number of subjects, but in this study where represented the best male and female jumpers in the world.

METHODS

Participants

The research included:

- Male ski jumpers (n=30) who jumped in the second series on the smaller Olympic hill HS106 m (start gate 13) on 6 February 2022 at 20:07.
- Female ski jumpers (n=30) who jumped in the second series on the smaller Olympic hill HS106 m (start gate 14) on 5 February 2022 at 20:00.

Statistical analysis

The criterion variable of competitive performance was the sum of the points of the variable jump length (m) and the judges' evaluation (points). The following variables were included among the independent variables: in-run velocity (m/s); take-off velocity at a point 30 m after the end of the take-off table (m/s); velocity of movement of the jumper at landing (m/s); the V-angle between the skis at a point 30 m after the end of the take-off table (degrees); wind speed (m/s).

The data source is the official results of the International Skiing Federation FIS, and the publication of the data during the television broadcast of the competitions. The data were processed using a computer statistical program (SPSS). First, the descriptive statistics of all variables were calculated. The correlation between the variables was calculated using the linear correlation coefficient. The correlation coefficients were evaluated at 5 % risk level ($p < 0.05$). At the end of the processing, a factor analysis of all variables was carried out.

RESULTS

The variability of jump length was significantly lower in men than in women (Table 1).

Table 1. Descriptive statistical characteristics and regression analysis of second jump for men (M) and women (W) on the Jumping hill HS106 m, WOG Beijing 2022.

Regression Men	***n***	***Min***	***Max***	***M***	***SD***	***r***	***beta***	***Sig beta***
Second jump length (m)	29	85.0	104.5	98.0	3.9			
In-run velocity (km/h)	29	86.7	88.0	87.4	.26	.22	.31	.17
Flight velocity 30 m (km/h)	25	86.2	94.2	89.2	1.9	-.14	-.10	.62
Landing velocity (km/h)	25	98.9	107.9	105.2	2.3	-.15	-.26	.26
Wind speed (m/s)	29	-.61	.43	-.26	.24	**.42**	.38	.07
Angle between skis (degrees)	25	23.0	45.0	34.4	5.1	-.14	-.11	.57
Mult R = 0.54	% of Var = 28.6		Sig R = 0.23					
Regression Women	***n***	***Min***	***Max***	***M***	***SD***	***r***	***beta***	***Sig beta***
Second jump length (m)	30	65.0	100.0	85.0	8.3			
In-run velocity (km/h)	30	85.7	87.7	87.0	.50	**.59**	.44	**.00**
Flight velocity 30 m (km/h)	30	84.2	93.5	88.1	2.2	.24	.23	.12
Landing velocity (km/h)	30	95.1	107.9	101.6	3.6	**.59**	.30	**.05**
Wind speed (m/s)	30	-.81	.84	.22	.41	.26	.30	**.05**
Angle between skis (degrees)	30	20.0	42.0	30.5	5.2	.12	.23	.12
Mult R = **0.78**	% of Var = **53.2**		Sig R = **0.00**					

Competitive results in one series reflect the jump length achieved and the performance in the style evaluation. Jump length contributed somewhat more to the first factor (factor of competitive performance) in the two selected series than the style scores.

Table 2. Results of the factor analysis of the selected variables (after Oblimin oblique rotation).

	F1 M	**F1 W**	**F2 M**	**F2 W**	**F3 M**	**F3 W**	**C M**	**C W**
F1	**Competitive performance factor**							
Competitive performance	**.98**	**.98**	.02	-.01	-.15	-.11	.97	.96
Jump length	**.95**	**.94**	.07	.21	-.40	-.06	.95	.95
Style scores	**.93**	**.85**	-.09	-.15	-.24	-.03	.88	.77
F2	**Wind Speed Factor**							
Wind speed	.22	.04	**-.99**	**.98**	.11	.23	.98	.97
F3	**The take-off speed factor & the speed of the 1st part of the flight**							
In-run velocity	.20	.68	-.03	-.04	**.76**	**-.58**	.63	.71
Flight velocity at 30 m	-.04	.42	.15	-.57	**-.63**	**-.57**	.43	.64
Landing velocity	-.15	**.69**	-.03	.03	**.76**	-.12	.65	.49
Angle between skis	-.04	.06	.15	.30	-.54	**.91**	.30	.89
% of total variance	39.5	46.8	17.5	25.8	20.0	10.2	**77.0**	**82.8**

Notes. F1, F2, F3 – significant factors, C - cumulative variance, M - men, W - women

DISCUSSION

On average, women had 13 m shorter jumps than men in the final series (Figure 1).

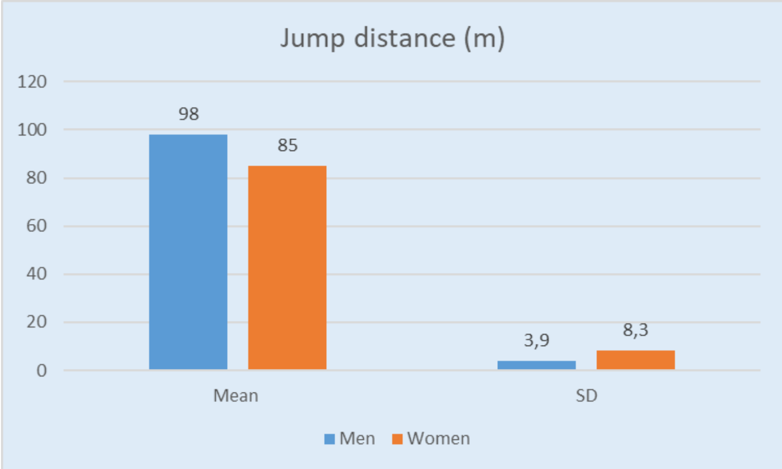

Figure 1. Length of the final jump at the 2022 Beijing Winter Olympics on the small hill HS106 m (men and women).

The average in-run velocity (Figure 2) was slightly lower than the flight velocity at a point 30 m behind the end of the take-off table for both men (by 1.8 km/h or 2%) and women (by 1.1 km/h or 1.3%).

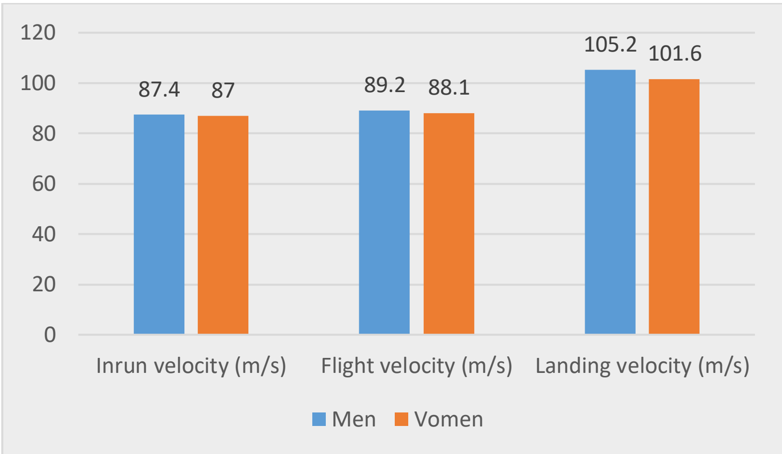

Figure 2. Relationship between average values of in-run velocity, flight velocity 30 m after the end of the take-off table (H30m) and landing velocity.

The wind influence is, in general, a fairly independent factor for the competitive performance of ski jumpers (Table 2). The influence of wind calculations in competitions is problematic because medal winners are decided by small differences (for example, differences of up to 3 points). In competitions that are under stronger influence of the wind and where the starting gate changes during the series, the wind and the starting gate may have a strong, random impact on the length of the jump, which then does not represent the true quality of the ski jumpers. This problem is present in all outdoors winter sports that are affected by weather conditions.

On the smaller HS106 m ski jump, Olympic medals were won by narrow margins for both men and women. The female Olympic champion U. B. defeated the second-ranked competitor by

2.2 points. The male Olympic champion R. K. won first place with an advantage of 4.2 points. For women, the first four ranked competitors differed greatly in terms of quality from the rest of the competitors; the fifth-ranked competitor was already 14.6% behind the winner.

For women, the multiple correlation was significantly higher than in men. This is probably due to greater variability in both the criterion variables of the length of the jump and the selected independent variables. The statistically significant percent of the variance length of the second jump (53.2%), can be explained by the selected factors: landing velocity, in-run velocity, and wind speed. The differences in the variability of the quality of the female ski jumpers are much greater than that of the males. They will certainly decrease in the future.

The women jumped using the start gate one higher than the men. The women's winner U. B. reached an in-run velocity of 87.4 km/h and a jump length of 100 m from start gate 14. The men's winner R. K. reached a slightly higher velocity of 87.6 km/h and jumped 99.5 m using start gate 13. This exceeded the average length of jumps in the men's competition by 1.5 m or 0.4 standard deviations. The female winner exceeded the average jump length by 15 m or 1.7 standard deviations. The male winner jumped with a tailwind (-0.53 m/s), and the female winner jumped with a slight headwind (0.12 m/s). The differences in competitive performance between men and women are still large. Women's competitive ski jumping has only been developed purposefully in the last 20 years. The number of female athletes is growing and their quality is also gradually increasing. The best female jumpers in the world can already achieve very good competition results.

The male jumpers had a 0.4 km/h higher average in-run velocity than the women, despite the lower start gate. The higher average in-run velocity is probably a reflection of the slightly higher average body weight of the men.

A high correlation (r = .59) between jump length and in-run velocity was found on the same hill for women. More than a third of the competitive performance in terms of jump length was determined by in-run velocity. Better female competitors also generally had a higher in-run velocity. The average in-run velocity for women was even lower (87.0 km/h) than for men (87.4 km/h), even though the women started from a higher take-off position. The variability of in-run velocity in women (0.50) was almost twice that of men (0.26). Differences in in-run velocity are the result of the influence of many factors (Jošt, 2009; Vaverka, F. (1987). Among these are objective factors (quality of jumpers' equipment and technology of preparing skis; influence of weather conditions) and subjective factors (the in-run technique; morphological factors). The low variability in men's in-run velocity also resulted in a low non-significant correlation (r = .22) between jump length and in-run velocity.

The increase in flight velocity in the first 30 meters compared to in-run velocity was not pronounced. The difference in average flight velocity at the point 30 m after the end of the take-off table did not significantly increase between the women and men (only by 0.7 km/h). There was no significant increase in the average velocity in the first part of the flight, but in the middle and final part of the flight, the average velocity of the flight increased significantly. Considering the relatively low in-run velocity variability, the variability of the flight velocity at the point 30 m after the end of the take-off table and also of the landing velocity increased significantly. These differences are related to the quality of the ski jumpers' flight technique, which is reflected in the angle and velocity of their flight (Vodičar & Jošt, 2011). Better jumpers simultaneously maintain a higher horizontal flight velocity and a smaller flight angle (Janura, Cabell, Svoboda, Elfmark & Zahalka, 2011; Jošt, Vaverka, Kugovnik & Čoh, 1998; Jošt, Čoh, Pustovrh & Ulaga, 1999; Virmavirta, Isolehtoa, Komi, Brüggemann, Müller & Schwameder 2005). For the first 30 meters after the jumpers take off, the flight angle is minimal (it varies from 9 to 20 angular degrees). During the take-off phase, the influence of air resistance is dominant, reducing the horizontal component of the take-off velocity.

During the take-off phase, the jumper moves the skis into a V-position (the V-angle between the skis reaches approximately 30 degrees). In this case, the longitudinal turning of the skis (canting) must be as small as possible. The average V-angle (Figure 3) was slightly higher for men (Mean = 34.4; SD = 5.1) than for women (Mean = 30.5; SD = 5.2). The difference was only 3.9 angular degrees, and the variability of the angle was almost exactly the same for men and women.

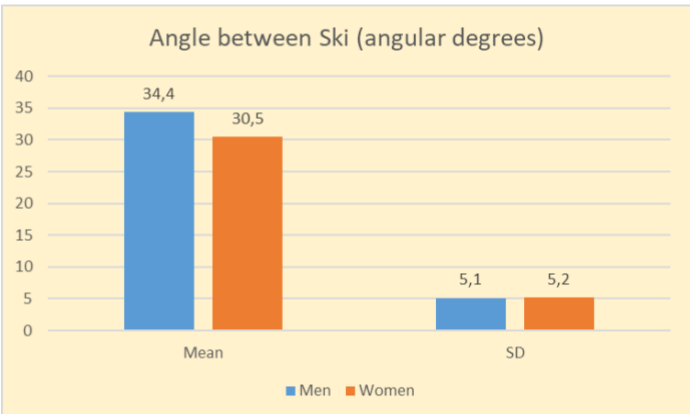

Figure 3. Angle between the skis at a point 30m after the end of the take-off table, WOG Beijing 2022, HS106 m hill.

In the middle part of the flight, the angle between the skis can increase by about 5 degrees. On larger ski jumps, the correct positioning of the skis during take-off is even more important (Jošt, Čoh & Vodičar, 2013). Of course, an optimal overall take-off and flight technique is always required and that includes the overall positioning of the jumper's body and skis (Norstrud & Ǿye, 2009; Vodičar & Jošt, 2017). As a favourable aerodynamic position, Marqués-Bruna and Grimshaw (2009) suggest a V-angle between the skis of 30 degrees and an angle between the body and the horizontal axis of 10 degrees. The range of variability of the V-angle was quite pronounced (between 24 and 44 degrees). In the first part of the flight, at a low flight angle, a rapid and large opening of the skis into the V-position is aerodynamically undesirable (Seo, Murakami & Yoshida, 2004). In the second part of the flight, a larger angle between the skis can generate better aerodynamic flight efficiency, of course, assuming an optimal overall aerodynamic flight technique. Excessive longitudinal canting of the skis can have a rather negative effect on the length of the jump. According to Mahnke and Mross (1992), the differences in the length of the jump are insignificant up to an angle of 10 degrees, between 10 and 20 degrees, the length of the jump can decrease by up to 5%, and increasing the angle of canting of the skis above 20 degrees can quickly lead to drastic reduction in jump length of up to 10%. According to Virmavirta and Kivekäs (2019), a slight canting of the skis between 5 and 10 angular degrees can even increase the aerodynamic efficiency of the flight. This arrangement of the skis can also contribute to a more stable position of the jumper's body and the skis during flight. The "Angle between the skis" variable was not significantly related to jump length in any of the selected series.

Larger differences appeared between the average in-run velocity and the average velocity before landing. For men, the difference was 17.8 km/h, or 20.3%, and for women, 14.6 km/h, or 16.7%. For women, competitive performance in the final series was strongly correlated with landing velocity ($r = .59$; $p < 0.05$). Landing velocity depends on the length of the jump – the longer the jump the higher the velocity. In the middle and final parts of the flight, the flight angle increases and can even reach more than 40 angular degrees. This increases the vertical velocity of the jumper's fall, which is constantly increasing due to gravitational acceleration. Of course, the influence of the aerodynamic conditions on the hill is important (Virmavirta & Kivekäs, 2012). With a headwind, the increase in velocity will be less than with a tailwind (Virmavirta & Kivekäs, 2022). Due to the increasing flight angle, the vertical velocity of the jumper's fall increases, which is also reflected in the increase in the resultant flight velocity. The Olympic competition took place at a relatively high altitude (about 1700 m), where the air density is already lower and this can cause up to 20% worse aerodynamic flight conditions, according to Schmölzer and Müller (2005). In these conditions, differences in the quality of flying technique between jumpers can be even more pronounced.

Jump length in the final series was significantly related to wind speed ($r = .42$; $p < 0.05$) and the wind compensation associated with it. The better jumpers generally had slightly more favourable wind conditions. The average wind speed was relatively low (-0.26 m/s), resulting in an average gain of 0.22 points. Olympic champion Ryoyu Kobayashi had a tailwind for both jumps. In the final series, he had a fairly bad tailwind (-0.53 m/s) and therefore received compensation of 5.1 points (equivalent to about 2.5 m jump length). Fortunately, the wind conditions were quite favourable for ski jumpers in the Olympic competitions. Otherwise, the influence of the wind on the length of jumps in an individual series can be quite strong and can have a completely different effect for each individual jumper (Virmavirta & Kivekäs, 2012).

Judges' scores were an integral part of the competitive performance factor in both selected series. Judges generally award higher scores to jumpers with longer jumps. This is probably due to the stronger aesthetic impression that long jumps make on judges. The longest jumps are simply more beautiful and attractive than shorter jumps. Judging problems arise when different start gates are used in the same series. Sometimes the weaker jumpers at the beginning jump from higher start gates and achieve jumps even close to the K-point of the hill. Visually, these jumps are appealing, but the judges feel that the quality of the technique and the movement is not the same as what the best jumpers demonstrate later, even when jumping from lower start gates. The best jumpers may even achieve shorter jumps than the less good jumpers due to the lower start gates, and as a result, unfairly receive lower style marks from the judges. If all jumpers used the same start gate, the better jumpers would probably be much more successful and would therefore justifiably receive higher marks for style. Unfortunately, these cases happen too often in practice, which then harms the best jumpers.

For the best jumpers, the judges' scores can also have a decisive influence on the position on the podium or the determination of the winner of the competition. The judges mainly evaluate the differences according to the aesthetic component of the flight (these differences are not so significant) and the aesthetic component of the landing and the outrun (these differences can, as a rule, be much more pronounced and important). In the selected series, the judges' evaluations probably did not affect the order among the Olympic medal winners. A problem occurred in the men's HS106 m small Olympic ski jump event. The competitor in the fourth place missed out on the bronze medal by only 0.5 points. If, for example, one judge raised their score by half a point, there would be two Olympic bronze medallists. In ski jumping, in individual competitions, with small quality differences between the best competitors, judges can have a strong or even decisive influence on who wins an Olympic medal. Wind conditions represented the second independent wind speed factor in both series, unrelated to competitive performance. The third significant factor was dominated by the projections of the variables of in-run velocity and flight velocity at a point 30 m after the end of the take-off table. The variables of landing velocity and angle between the skis did not form an independent factor.

CONCLUSION

Based on the results of the research study conducted on the men's and women's final ski jumping series on the smaller Olympic ski hill HS106 m at the Beijing 2022 Winter Olympics, the following key findings could be highlighted:

- The difference in mean jump length between men (Mean = 98 m, SD = 3.9 m) and women (Mean = 85 m, SD = 8.3 m) was high. Men had a higher mean value and lower variability in jump length. Only a few of the best women could reach the average length of the men.
- The in-run velocity had a statistically significant correlation with jump length in women ($r = .59$; $p < 0.05$). The variability of in-run velocity in women was significantly higher than in men.
- Flight velocity at 30 m after the end of the take-off table was not significantly related to jump length. Variability in men was much higher for this variable than for in-run velocity.
- Landing velocity was statistically significantly related to the jump length in women ($r = .59$; $p < 0.05$). In general, women with longer jump lengths also achieved higher landing velocities.
- The variable Angle between the skis at the point 30 m after the end of the take-off table had no significant correlation with the jump length. Large differences were measured in men, between 24 and 44 angular degrees.
- The correlation between wind speed and jump length was statistically significant for men ($r = .42$; $p < 0.05$).

- For women, the multiple correlation (Mult R = .78) was significantly higher than in men (Mult R = .54). This is probably due to greater variability in both the criterion variables of the length of the jump and the selected independent variables.

We are aware that the research was conducted at an official competition and that it was difficult to obtain adequate data on additional factors of competitive performance of male and female ski jumpers. Thus, the research was focused only on those factors that could be studied at the competition itself.

The research thus provided interesting findings that are particularly important for the practical aspect of training top ski jumpers (male and female). The fundamental insight is that top performance is always influenced by multiple factors, which require coaches to take the most directed approach to their development.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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