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INFLUENCE OF THE START NUMBER ON ELITE ALPINE SKIING COMPETITORS' RESULTS

VPLIV ŠTARTNE ŠTEVILKE NA REZULTAT VRHUNSKIH TEKMOVALCEV V ALPSKEM SMUČANJU

ABSTRACT

The study aimed to establish whether there is a relationship between competitors' start numbers and the times they achieved in individual course sections in a Slalom competition at the Europa Cup. The study included the top 15 ranked competitors in the first run who had been drawn for the starting order. The course was divided into eight sections and the times were measured for each section separately and for the entire course using computer-aided video analysis. The coefficient of variation (CV) showed that the differences between the competitors in terms of achieved times were larger mainly on the steeper sections of the competition course (CVPT/1 = 11.3%; CVPT/5 = 12.5%; CVPT/6 = 15.9%; CVPT/7 = 17.7%). This was also confirmed by the calculation of correlations among the achieved times in eight course sections and the final achieved time (S1: Sig. = 0.01; S2: Sig. = 0.00; S5: Sig. = 0.00; S6: Sig. = 0.01). In the steeper course sections, the correlations between the start numbers and the achieved times in individual course sections were also statistically significant (S1: Sig. = 0.029; S5: Sig. = 0.055). We can conclude based on the results that the influence of the start number can be observed already with the competitors who started first, and that the start number significantly influences a competitor's final ranking, especially in the steeper course sections. This also applies to the conditions where the course has been hardened and prepared for competition.

Key words: Europa Cup, kinematics, slalom, time

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IZVLEČEK

Z raziskavo smo želeli ugotoviti povezanost med štartno številko tekmovalcev in njihovimi doseženimi časi v posameznih odsekih proge na tekmovanju za Evropski pokal. V raziskavi je sodelovalo prvih 15 rangiranih tekmovalcev, ki so v prvem teku tekmovanja startali po vrstnem redu. Postavitev je bila razdeljena na osem odsekov. Čas vsakega odseka posebej in tudi dosežen čas celotne postavitve je bil izmerjen s pomočjo računalniške video analize. Koeficient variacije (CV) je pokazal, da so bile razlike v doseženih časih med tekmovalci večje predvsem na strmejših odsekih tekmovane proge (CVPT/1 = 11.3%; CVPT/5 = 12.5%; CVPT/6 = 15.9%; CVPT/7 = 17.7%). Slednje je potrdil tudi izračun korelacij med doseženimi časi 8 odsekov proge in končnim doseženim časom (S1: Sig. = 0.01; S2: Sig. = 0.00; S5: Sig. = 0.00; S6: Sig. = 0.01). V strmejših odsekih proge so bile statistično značilne tudi korelacije med štartnimi številkami in doseženimi časi posameznih odsekov proge (S1: Sig. = 0.029; S5: Sig. = 0.055). Na podlagi rezultatov lahko zaključimo, da je vpliv štartne številke zaznati že med prvimi štartajočimi tekmovalci in da številka pomembno vpliva zlasti v strmejšeh odsekih proge na končno uvrstitev tekmovalca. Slednje velja tudi v pogojih, kjer je proga dobro utrjena in pripravljena za tekmovanje.

Ključne besede: Evropski pokal, kinematika, slalom, čas

INTRODUCTION

Alpine skiing is a complex sport where a competitive performance depends on a number of factors (Bandalo & Lešnik, 2009). The different configurations of the terrain and unstable conditions during competitions require competitors to have high levels of skiing skills and abilities (Žvan & Lešnik, 2000). When identifying the success factors in skiing compared to those sports where the conditions are more stable, it is much harder to include and measure everything that influences the execution of a turn.

Carrying out measurements in competitive skiing conditions is a challenging task. For this reason, measurements most often take place in adjusted conditions which are typically far from a real-life competitive situation. A paucity of research has been conducted in real-life competitive environments, and a common problem arising particularly in measurements involving elite Alpine skiers is the small size of the sample of subjects. Regardless of the above, a number of studies have been conducted in the area of Alpine skiing. These delved into competitive skiing and identified different influences on competitive performance (Ducret, Ribot, Vargiolu, Lawrence, & Midol, 2005; Luethi & Denoth, 1987; Platzer, Raschner, & Patterson, 2006; Savolainen, 1989; Supej, 2008; Supej, Kugovnik, & Nemec, 2002; Thompson, Friess, & Knapp II, 2001). In their investigations of young competitors' performances, authors have largely focused on basic and special motor abilities as well as anthropometric and psychological characteristics (Černohorski & Pustovrh, 2008). Besides psychophysical preparedness, elite competitors' achievement of good results depends strongly on the level of their competitive skiing technique (Federolf et al., 2008; Supej, Kugovnik, & Nemec, 2002; Supej, Kugovnik, & Nemec, 2004), their physical fitness, their ability to concentrate and their motivation (Duda & White, 1992; Tušak, 1999; Tušak, 2000; Vallerand & Fortier, 1998), most probably also on the starting number (Supej, Kugovnik, & Nemec, 2005) and the quality of their equipment to which coaches attribute a great deal of importance, along with some other factors.

Analyses of different competitive skiing techniques and studies of other performance factors in Alpine skiing have contributed significantly to the development of modern techniques of skiing between the gates (Müller, Bartlett, Raschner, Schwameder, Benko-Bernwick, & Lindinger, 1998; Supej, Kugovnik, & Nemec, 2002; Supej, Kugovnik, & Nemec, 2004; Supej, Kugovnik, & Nemec, 2005). These tend to advocate the execution of a turn on the ski edge, without skidding sideways, so as to reduce energy loss. For this purpose, a series of studies has been conducted in recent times that apply new methods to investigate the energy loss during different executions of competitive skiing turns (Reid et al., 2009; Supej, 2008; Supej, Kipp, & Holmberg, 2011). It has been proven in individual course sections that these differences can be very large, even between elite competitors. It is known that the final score in a competition often depends on how individual sections of the course were skied (Supej & Cernigoj, 2006), and that the final result of the run through a given combination of gates can largely depend on the competitors' starting order (Supej, Nemec, & Kugovnik, 2005). Even though it has been proven that a certain number of competitors skiing down the slope affects the condition of the course, to our knowledge no studies have investigated whether the start number influences the final result in competitions. Further, it could be expected that different parts of the course can deteriorate to different degrees depending on the start number and thus influence the final result in different ways.

Therefore, the aim of the study was to establish whether there is a relationship between a competitor's start number and the times achieved in individual course sections and/or overall time. It was hypothesized that the starting number is having an impact on the on course section as well as overall times and that the differences in sections times among competitors will be greater when skiing on more difficult course sections.

MATERIALS AND METHODS

The study included the top 15 skiers during their first run in the Slalom at the Europa Cup (EC) races in Kranjska Gora, Slovenia. All participants competed under the auspices of the International Ski Federation (FIS). The experiment was conducted with the organiser's prior approval (the Vitranc Cup Organising Committee). The study was approved by the Ethics Committee of the Faculty of Sport.

Kinematic measurements were carried out with all study subjects using three Sony HC7 high-definition (HD) pan-tilt-zoom mini DV cameras each attached on a separate tripod (Sony Corp., Tokyo, Japan). The three cameras covered the bulk of the course from the start to the finish (Figure 1). The part of the course from the start to the first gate, the last gate before the finish and the double gates marking the passage between the course sections were left out. Using the deinterlacing technique, the odd and even fields were separated into frames, thus producing 50 Hz recordings in a half-HD vertical resolution; these were resized into 50 Hz HD recordings with a bicubic resize filter. The video recordings were analysed with the SX Video Compare v3.3 pro software (Intelligent Solutions and Consulting s.p., Slovenia, Kranjska Gora) which enabled a time analysis using three stopwatches accurate to ±0.01 s (Figure 2). The recordings of the course from the three video cameras were divided into eight sections depending on the terrain characteristics and setting of the gates (Figure 1). In this way the times achieved by each study subject in eight consecutive sections of the Slalom course were obtained.

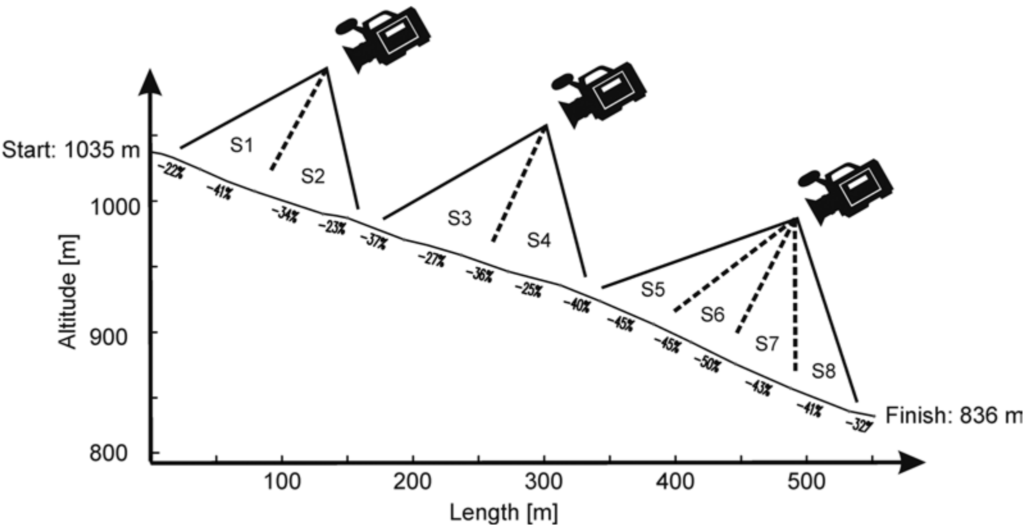

Figure 1. Cross-section of the terrain (topographic profile) and locations of the cameras which covered the 8 sections (S1–S8).

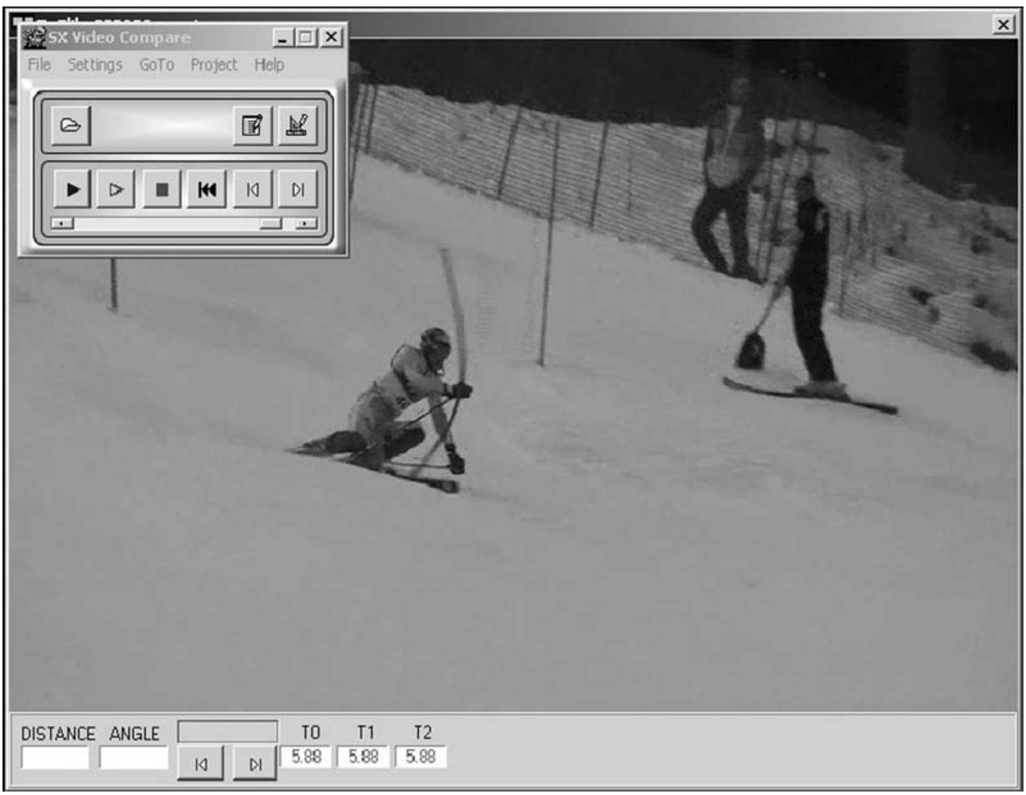

Figure 2. An example of the computer video-analysis using the SX Video Compare software package; a skier beside a pole.

Mean values of the section times and the overall time (Mean AT) as well as the corresponding coefficients of variations (CV) were calculated. The normality of the distribution of the results of individual course sections was verified with skewness and kurtosis coefficients. In addition, the influence of the start number on the overall and partial times of the first round of the Slalom at Kranjska Gora was tested with Wilcoxon's signed-rank test and Pearson's correlation coefficient. Pearson's correlation coefficient was also used to test the influence of the achieved section times on the overall time. Statistical significance was set at $p < 0.05$. The data were processed with the IBM SPSS 21 statistical software package.

RESULTS

Table 1 shows that of the analysed first 15 competitors in total, 13 completed the first Slalom run at Kranjska Gora; 2 skiers did not complete the last section of the slalom. The competitors achieved the longest average time in the first section (PT/1: Mean AT = 5.652 s), whereas the shortest average time was recorded in section five (PT/5: Mean AT = 4.167 s). Larger coefficients of variation (CV) were observed in sections 1 (CVPT/1 = 11.3%), 2 (CVPT/2 = 12.6%), 5 (CVPT/5 = 12.5%), 6 (CVPT/6 = 15.9%) and 7 (CVPT/7 = 17.7%).

Table 1. Basic statistics of the competitors' achieved times, differences and deficits in individual course sections and in the bulk of the Slalom course setting for the Europa Cup at Kranjska Gora

	PT/1	PT/2	PT/3	PT/4	PT/5	PT/6	PT/7	PT/8	OT
N1	15	15	15	15	15	15	15	13	13
N2	0	0	0	0	0	0	0	2	2
Mean AT [s]	5.652	5.401	4.255	4.833	4.167	4.812	4.865	4.408	38.346
CV [%]	11.3	12.6	5.4	6.2	12.5	15.9	17.7	9.7	1.6

Legend: PT/x – partial time in section x = 1 to 8; **OT** – overall time; **N1** – number of classified competitors; **N2** – number of disqualified competitors; **Mean AT** – average time; **CV** – coefficient of variation

When testing the differences among medians (Wilcoxon's test), statistically significant differences between the start numbers of the competitors and their achieved times in all sections were observed, except for the first section (SN/1: Sig. = 0.088) and for the second section where only a trend was observed (SN/2: Sig. = 0.053).

Table 2. Results of the Wilcoxon test between the start number and performances in individual course sections and the bulk of the Slalom course setting during the Europa Cup at Kranjska Gora

	SN/1	SN/2	SN/3	SN/4	SN/5	SN/6	SN/7	SN/8	SN/O
Z	-1.704[b]	-1.931[b]	-2.499[b]	-2.272[b]	-2.542[b]	-2.272[b]	-2.215[b]	-2.132[b]	-3.180[c]
Sig.	.088	.053	.012	.023	.011	.023	.027	.033	.001

Legend: SN/x – start number in section x = 1 to 8; **SN/O** - start number/overall time, **Z** – Z-score; **a.** - Wilcoxon Signed-Ranks Test; **b.** – Based on negative ranks; **c.** – Based on positive ranks; Sig. – significance of the test

Table 3 shows that the influence of the start number on the times achieved was statistically significant only in section 1 (Sig. < 0.05), but we observed a trend in sections 5 and 6 (SN/S5: Sig. = 0.055*; SN/S6: Sig. = 0.063, respectively). In all sections, competitors with lower start numbers achieved better times and were thus ranked higher in the competition. In the other sections of the race, the influence of competitors' start numbers on their achieved times was not found to be statistically significant. The influence of the start number on the overall time was not statistically significant, but a trend was observed (SN/O: Sig. = 0.088).

Table 3. Results of paired Pearson's correlation coefficients between the start number and performances in individual course sections and the bulk of the Slalom course setting during the Europa Cup at Kranjska Gora

Pairs		N	Corr.	Sig.
Pair 1	**SN/S1**	15	.562	**.029***
Pair 2	**SN/S2**	15	.442	.099
Pair 3	**SN/S3**	15	-.125	.657
Pair 4	**SN/S4**	15	-.248	.372
Pair 5	**SN/S5**	15	.505	**.055***
Pair 6	**SN/S6**	15	.492	.063
Pair 7	**SN/S7**	15	-.004	.990
Pair 8	**SN/S8**	13	.337	.260
Pair 9	**SN/O**	13	.491	.088

Legend: SN – start number; **Sx** – section of course x = 1 to 8;
N – number of subjects; **Corr.** – correlations;
Sig. - significance (Sig. < 0.05*, Sig. < 0.01)**

In addition, the effect of the achieved times in the eight sections on the overall time was tested. The Wilcoxon test revealed statistically significant differences among all section times and the overall time of the first race (Sig. < 0.01). Table 4 shows Pearson's correlation coefficients for the influence of the achieved times in each section to the overall time. The differences were statistically significant in the sections 1 (S1/O: Sig. =

0.013**), 2 (S2/O: Sig. = 0.000**), 5 (S5/O: Sig. = 0.000**), 6 (S6/O: Sig. = 0.001**) and 8 (S8/O: Sig. = 0.000**).

Table 4. Results of paired Pearson's correlation coefficients between the section times and the overall time of the Slalom course setting during the Europa Cup at Kranjska Gora

Pairs		N	Corr.	Sig.
Pair 1	**S1/O**	15	.666	**.013****
Pair 2	**S2/O**	15	.876	**.000****
Pair 3	**S3/O**	15	.342	.252
Pair 4	**S4/O**	15	.120	.697
Pair 5	**S5/O**	15	.831	**.000****
Pair 6	**S6/O**	15	.803	**.001****
Pair 7	**S7/O**	15	.452	.121
Pair 8	**S8/O**	13	.879	**.000****

Legend: Sx – section of course x = 1 to 8; **O** – overall time; **N** - number of subjects; **Corr.** – correlations;
Sig. – significance (Sig. < 0.05*, Sig. < 0.01)**

DISCUSSION AND CONCLUSIONS

The main findings of the study were that in the subject Alpine skiing competition the results achieved in individual sections of the course and the overall result were importantly influenced by the start number. The influence of the start number can be detected already with the first starting competitors. The start number has a considerable influence on the final ranking of a competitor, especially in the steeper course sections, which is also true in the conditions where the course has been hardened and prepared for the competition, as was the case in this study.

The results of the study showed that the overall competition result is strongly influenced by the start number (Table 3) even if only the first 15 skiers are considered in Europa Cup races who have drawn starting numbers (i.e. a randomly selected starting order or a starting order that does not follow the performance quality of skiers). This means that the situation on the course during the whole race can deteriorate considerably, which is in line with previous findings that investigated the worst-case scenario (Supej, Kugovnik, & Nemec, 2005). The pilot study first dealt with all competitors (107 in total) who participated in the competition. However, it is difficult to claim for all competitors from start number 15 onwards that the difference in the measured times is only a consequence of the influence of the start number. In contrast to the first 15 competitors, these competitors start depending on their achieved EC or FIS points, reflecting their quality.

According to the present results, it seems that even if the snow conditions during the investigated competition were such that the course was relatively well preserved until the end of the competition, one cannot claim that those competitors with higher start numbers skied in equivalent conditions to those of competitors with lower numbers. Other advantages at the competition included the relatively constant temperature and the fact that some sections of the course were not sunlit. This is extremely important because the temperature can significantly affect the ski friction (Buhl, Fauve, & Rhyner, 2001) and thus the overall result. In addition, the radiation of the sun itself can affect the friction (Colbeck & Perovich, 2004).

All of the investigated skiers skied through the first seven sections of the course. Only in section 8 were two of them disqualified (Table 1). Thus in all sections, except the last one, an identical sample was investigated. The competition was staged on demanding and relatively long terrain where World Cup races also take place. Because the only two skiers were disqualified in the last section, which is not the steepest, it may be concluded that the disqualifications involved competitors' fatigue and/or the desire to 'finish'.

Previous studies demonstrated the existence of two types of turns: turns with skidding and carving turns which are more or less successfully executed, depending largely on the technique applied (Supej, Kugovnik, & Nemec, 2002; Supej, Kugovnik, & Nemec, 2004). It is thus interesting that the differences in the recoded times are the largest on the steeper course sections where a significant impact on the overall time was observed as well (Table 4). Fewer turns without skidding are expected in these sections. Moreover, the results showed a direct correlation between the start number and sections 1, 5 and 6 (Table 3) where the course was the steepest. These correlations on steeper course sections can also be associated with more skidding as we can expect that, in such steeper sections, the competitors must ski with greater speed control. The use of the course and skidding can be related to the interaction between the skis and the snow. Namely, skidding involves the "planing" of snow or the so-called "metal cutting theory" (Heinrich, Mössner, Kaps, & Nachbauer, 2010), which most probably causes the strongest wearing out of the course. On the other hand, during a carving turn the ski mainly carves with the edge through the snow and the snow compresses (Yoneyama, Kagawa, & Osada, 2009); at the highest-ranking competitions the snow is icy and has a relatively low level of compression.

Besides a significant correlation between the start number and the times of individual steeper sections, high and statistically significant coefficients of correlation were also observed on two slightly less steep sections (2 and 8). In this case, it can be concluded that the technical knowledge of the competitor is decisive, and particularly the amount of energy that the competitor brought with them when entering a section from the previous (steep) section (Supej, Kipp, & Holmberg, 2011). Since in the last section (8) the competitors are probably the most tired, such large differences between the competitors in terms of time may be a consequence of their tiredness (Tomažin, Dolenec, & Strojnik, 2008).

The highest coefficient of variation (Table 1) which was noticed in section 7 (CVPT/7 = 17.7%) is also interesting. In the mentioned section, despite the high CV, no correlation was observed between the start number and the achieved times in the section (Table 3) and no correlation between the time of the section and the total final time (Table 4); the section, like other sections, is related to the final total time. In this section, the differences could be ascribed to fatigue and, given the terrain configuration, also the complexity of the course, perhaps even the difficulty of the gate setting, but this was not controlled separately.

A limitation of this study is that it only encompassed one competition which took place on a single course in specific snow conditions and with a unique course setting. The results could have differed if the snow conditions were poorer, as shown in a previous study (Supej, Nemec, & Kugovnik, 2005), or if the course setting was different or on different terrain. Another possible limitation of the study is the different skills of the skiers, but the randomized starting number assured to minimize this affect. Potentially, another limitation of the study could be the measurement accuracy to ±0.01 s which was obviously sufficient considering the relatively large differences between the competitors in course sections. Greater accuracy could be achieved if a sufficient number of photocells is used to cover the equivalent sections; however, this is unfeasible due to the high safety standards in official competitions.

No studies have investigated the influence of the start number on high-ranking Alpine skiing competitions. The study results provide encouragement to deal with this subject systematically in the future. Therefore, our findings could serve as a basis for an in-depth study of the influence of the start number on Alpine skiing performance. The influence of the start number and the equality of the conditions for all competitors could be investigated and could underpin a decision to change the competition rules.

Ensuring the same conditions for all competitors in a competition does not only depend on the hardness of the course but, as is evident, also on the share of the steeper sections of the course and most probably the shift of the gates on the slope. If the shift is larger it is very difficult to ski down the slope without skidding. Therefore, to equalise the conditions for all competitors, the competitions could be organised on more gently sloping terrain and with more open settings. Such courses would be easier to ski without skidding and the course would be less worn out. The latter could serve as a starting point for the tactics of setting courses in competitions; however, one should be aware that competition courses are becoming increasingly steeper, not only in Slalom but also in other skiing disciplines. This can provide important guidance for the selection of terrain for competitors to train on. The number of higher or lower ranked competitors with whom a coach works can be very important information when setting the course in a competition that most perfectly suits their team in terms of tactics. A possible suggestion to the existing competition rules to equalize the conditions could be to separately randomize starting numbers also for the group of skiers between rank 16 and 30 and for the group of skiers with a rank above 30.

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