THE BEST SLALOM COMPETITORS - KINEMATIC ANALYSIS OF TRACKS AND VELOCITIES

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Abstract:

With the help of a kinematic analysis we tried to establish whether the competitors with a shorter line of skiing achieve higher velocities among the slalom gates. The first part of research found out that the competitors who had the shortest lines of skiing in the first analysed turn had, as a rule, the longest lines of skiing in the second turn and vice versa. The shortest line of skiing is therefore not a guarantee for the optimum entry into the next turn. This is confirmed by the negative and statistically insignificant degree of the correlation between the distances of the line of skiing of the competitors at the first and the second pole. On the basis of these findings, it could be claimed that under the present conditions, it is extremely difficult, maybe even impossible, to ski in such a way that the line of skiing would be very short in several successive turns. The second part of the research focused on the establishment of the correlation between the trajectories of the skis and the velocity of skiing of the chosen sample in the measured space (two slalom turns). The calculations of the correlations proved a statistically significant correlation between the average velocity of skiing and the average distance of the length of the line of skiing from the y-axis in the entire measured segment. It was established that the measured space was covered faster by the competitors whose line of skiing was shorter, which means more direct.

Key words: *alpine skiing, technique, slalom, kinematics, velocity of skiing, line of skiing*

Introduction

In top alpine skiing, the choice of technical and tactical elements is still left primarily to the momentary intuitive choices of an individual and his/her coach. These choices are probably most important but many times insufficient. In future, the process of coaching should therefore be more oriented towards the perfection of the competitive skiing technique under various conditions and in various circumstances. The use of the most modern methods of measuring is thus inevitable.

In the past few years, the exact study of the technique of movement has been based primarily on the establishment of kinematic parameters with the help of which it is possible to determine quite precisely the position of specific points and segments of the body in time and space (Müller & Schwameder, 2003, p. 679). On the basis of the established trajectories and other parameters of the movement of points in specific segments of skiing (important for success), it is possible to analyse precisely the segments of the performed movement. On the basis of these segments, the technique that has significantly improved in the past few years can be defined (Müller, Schiefermüller, Kröll, & Schwameder 2005, p. 15). Due to the tendency towards faster skiing, the most obvious step forward concerning the choice of the line of skiing among the gates has been noticeable lately. The choice of the line of skiing and the distance of the line of the turns from the gates is undoubtedly an important factor in competitions especially in technical events. Thirty years ago, a competitor only touched the pole with his/her shoulder, whereas today, the line of skiing runs right next to the pole, and the centre of gravity of a competitor is even above the pole.

The modern slalom technique has improved to such an extent also due to the development of equipment (geometry of skis). Interestingly, the skis with a pronounced side curve became established as late as the 1999/2000 season. There are numerous reasons for this, one of them being a worse quality of materials from which the skis were made at the beginning of their development (worse torsion resistance). To make a turn along the edges is conditioned by the marked angling of the edges. Due to this, the angle between the skis and the snow surface increases. Increasingly faster skiing causes great loads in turns (Müller, 1994, p. 263; Lüthi et al., 2005, p. 98). Often the skis did not perform well in the turn because of the bad torsion resistance. The consequences of this were side slides and imprecise turns.

Today, top competitors strive for increasingly faster skiing along the shortest possible line of skiing. Such a way of skiing is demanding and risky and consequently often not the right way to success. In a competition, success depends on many factors (Bosco et al., 1994, p. 12). From the point of view of technique, a good result is a consequence of the best relationship between the velocity of sliding and the choice of the line of turns in a particular pole setting (Pozzo, Canclini, Cofelli, & Platzer, 2005, p. 125).

The present day skis are faster in turns. The aim of each competitor is to make the entire turn along the edges without the so-called rotation of the skis, which always causes a smaller or greater side sliding. The rotation of the skis into a turn was typical of the old technique, and today, it represents only a method of controlling the velocity when skiing between the gates.

The choice of the line of skiing among the gates

As has already been stated, several factors exert an influence on the success in alpine skiing. Only some most important factors will be discussed. Among them, a more or less direct line of a turn at the highest possible velocity must be stressed.

In every sport, the development of an individual sportsperson is based on a pre-developed and determined programme, and alpine skiing is no exception. Of course, it happens many times that the programme of work and its effective realization begin to diverge. In this case, the programme must be redesigned and adapted to the new circumstances that exist in the programme–competitor relationship. First, young competitors must learn the proper technique which is improved over the course of time until it achieves a top performance (Hintermeister et al., 1995, p. 315). Later, the priority of coaching the technique should primarily be the development of the highest possible method of skiing and retaining the highest possible velocity during skiing. During skiing, the velocity keeps changing and it is the task of a competitor to preserve the optimum relation between decreasing and increasing the velocity (Kugovnik, Nemec, & Supej, 2005, p. 87).

In this study, we aimed at the following:

- to establish the differences in the choice of the line of skiing between individual competitors in the World Cup and to determine the distance of their lines of skiing from the pole (fall line) and
- to establish whether the competitors with a shorter line of skiing in the pole setting achieve higher velocities and consequently faster sliding among the slalom gates and, finally, a better result.

Methods

The characteristics of the slalom technique were studied on the basis of the kinematic measurements taken during the 2004 Vitranc World Cup slalom competition in Kranjska Gora. The test subjects were the best alpine skiers in the world who competed in the World Cup competitions under the auspices of Fédération Internationale de Ski (FIS). The sample of participants consisted of 18 competitors that had start numbers from 2 to 69. Only those who, according to the experts had skied through the track without any visual deviations that could affect the result in the measured section were included into the final analysis. This enabled us to take into account the competitors from the whole slalom ranking list who competed in the 2004 World Cup.

The data obtained were processed at the Institute of Sport at the Faculty of Sport of the University of Ljubljana. Each competitor was filmed with three pairs of synchronized cameras with the frequency of 25 Hz (one picture per 0.04 second). The recordings were then analysed with the program for biomechanical analyses (APAS system for kinematic analyses). In this way we obtained the coordinates of the points of ends of segments in space (x and y).

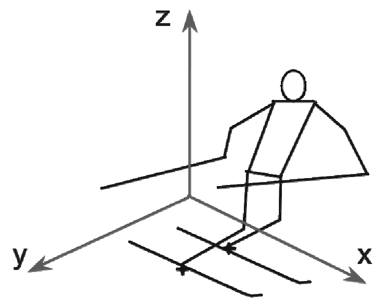


Figure 1. Model of a human being; 3D system of rigid bodies used for kinematic analysis.

On the basis of the distance of points of trajectories of the left and right ankles (arithmetic mean) we calculated for each individual competitor the average distance of the line of skiing from the fall line (y = 0) within the measured space. The measured space comprised two slalom turns. The experience of other researchers shows that the assessment of a skier's successfulness can best be made only if we analyse both turns and we also share this belief. The beginning of the new (and the end of the previous) turn was defined in the measured space for each competitor by means of the moment/place of crossing the trajectories of skis (arithmetic mean of the left and right ankles) and trajectories of the centre of gravity of the skier. The trajectory of the turn is therefore represented by the arithmetic mean of the trajectories of the left and right ankles around two poles which were part of the entire pole setting in the first run. The average distance of the line of skiing of the skier from point y = 0 (fall line) was calculated on the basis of the distance of all the points of the trajectory of the skis.

The second variable was the calculation of the average velocities of the skis (arithmetic mean of the ankles) in the measured segment of the slalom course in the competition. The average velocities were calculated on the basis of the absolute velocities of the competitors at the first pole, crossing of the trajectories of skis and the centre of gravity of the body (the change of edges) as well as at the second pole. On the basis of the absolute velocity in the points mentioned, the average velocity of an individual competitor was calculated in the measured segment (Vavg).

The average gradient of the slope in the measured space was 21.46 ± 2 %.

After the kinematic analysis the data obtained were processed with the SPSS statistical program. Besides the average values of velocities of individual segments of the body, the correlation between the individual variables which were determined regarding the goals that we had set was calculated.

Results

On the basis of the calculation of the trajectory of skis (arithmetic mean of ankles), the point of the trajectory closest to the first and second poles was determined for each competitor. In this way we tried to establish whether the distance of the line of skiing at the first and the second poles was similar in top competitors and to what an extent it differed.

Table 1 presents the values of the distances of trajectories of skis (from y-axis = 0) at the first pole for each individual competitor and the differences between the lines of competitors in comparison to the competitor No. 32, who skied closest to the first pole. According to our observations, the lines of skiing can differ by up to more than half a metre. Competitor No. 32 skied closest to the pole at the first gate (difference = 0.0 m), whereas the distance of competitor No. 10 from the first pole was as much as 0.504 metre.

Table 2 presents the values of the distances of trajectories of skis (from y-axis = 0) at the second pole for each individual competitor and the differences between the lines of competitors in comparison to the competitor No. 2, who skied closest to the second pole. According to our observations, the distances from the pole do not differ to such an extent (less than 30 cm) in comparison to the lines around the first pole. Competitor No. 2 skied closest to the pole at the second gate, whereas the distance of competitor No. 32 from the second pole was as much as 0.289 metre.

Table 1. Differences between competitors regarding the distance of the line of skiing from the y-axis at the first pole

Order	Start no.	Distance at the 1st pole (m)	Difference (m)
1	32	2.664	0.000
2	4	2.679	0.015
3	43	2.718	0.054
4	9	2.739	0.075
5	3	2.759	0.095
6	69	2.795	0.131
7	2	2.801	0.137
8	22	2.821	0.157
9	27	2.832	0.168
10	21	2.852	0.188
11	44	2.856	0.192
12	5	2.870	0.206
13	55	2.908	0.244
14	60	2.957	0.293
15	15	2.964	0.300
16	6	2.993	0.329
17	17	3.044	0.380
18	10	3.168	0.504

Table 2. Differences between competitors regarding the distance of the line of skiing from the y-axis at the second pole

Order	Start no.	Distance at the 2nd pole (m)	Difference (m)
1	2	3.310	0.000
2	60	3.350	0.040
3	15	3.404	0.094
4	10	3.427	0.117
5	5	3.443	0.133
6	43	3.452	0.142
7	3	3.457	0.147
8	6	3.480	0.170
9	22	3.480	0.170
10	27	3.484	0.174
11	9	3.489	0.179
12	4	3.517	0.207
13	55	3.534	0.224
14	17	3.540	0.230
15	44	3.570	0.260
16	69	3.582	0.272
17	21	3.590	0.280
18	32	3.599	0.289

It is necessary to point out that the data for the line of skiing of an individual are a result of the arithmetic mean of the ankles. Different distances between both skis, very often also a more/less stretched outer leg and therefore the outer ski that is further from or closer to the pole can exert an influence on that. The previously mentioned data can therefore serve us as mere support in further analyses.

With the help of the calculation of correlations between the distances from the first pole and the distances from the second one, we established whether the distances of the competitors' lines of skiing from the first pole and from the second one were approximately equal. That means that the competitors whose lines of skiing were closer to the first pole were, as a rule, further away from the second pole and vice versa. It has to be stressed that competitor No. 2, who skied closest to the second pole, actually skied closest to both poles in comparison to the entire sample measured. His average distance from the y-axis at the first and second poles was 3.05 m (the average is calculated on the basis of the results presented in Tables 1 and 2). Competitor No. 32, who skied closest to the first pole, but due to a longer line around the second pole, his average distance from the y-axis was slightly greater at both poles (3.13 m; the average is calculated on the basis of the results presented in Tables 1 and 2).

Table 3. The calculation of the correlation between the distances of the competitors' lines of skiing from the y-axis at the first and second poles

Correlation		Distance at the 1st and the 2nd pole
Distance at the 1st and the 2nd pole	Pearson Correlation	-.256
	Sig. (2-tailed)	.304
	N	18

Legend:
distance at the 1st and at the 2nd pole
→ distance of the middle part of the ankles along the y-axis at the first and at the second pole (in metres)
Pearson Correlation
→ value of the correlation coefficient
Sig. (2-tailed) → statistical significance of the correlation coefficient
N → number of test subjects

Table 3 shows a negative correlation coefficient (Pearson's correlation coefficient = -0.256). That means that the competitors who were further away from the y-axis at the first pole were, in most cases, much closer to the y-axis at the second pole and vice versa. A typical example is competitor No. 32, whose line of skiing was closest to the first pole and furthest from the second pole. At the same time, we have to stress that no competitor had a very short line of skiing at both successive poles in the measured space. No competitor was very far away from both poles from point 0 regarding the y-axis. The question whether it is possible to ski in this way around several successive gates is therefore appropriate. It can be claimed that in slalom it is impossible to talk about the ideal line of skiing and that the optimum line of skiing is the one which guarantees the skier the smallest loss of velocity in turns (Wimmer & Holzner, 1997, 208).

Table 4. Competitors listed according to average velocities reached (Vavg) and according to average values of the distance of the line of skiing (line/AVG) from the y-axis (y = 0) in the measured segment

place	Start no.	Vavg	place	Start no.	line/AVG
1	15	12.535 $^{m}/_{s}$	**1**	4	1.267 m
2	10	12.403 $^{m}/_{s}$	**2**	10	1.268 m
3	3	12.389 $^{m}/_{s}$	**3**	55	1.305 m
4	2	12.382 $^{m}/_{s}$	**4**	2	1.344 m
5	5	12.208 $^{m}/_{s}$	**5**	43	1.351 m
6	44	12.166 $^{m}/_{s}$	**6**	5	1.359 m
7	17	12.165 $^{m}/_{s}$	**7**	21	1.366 m
8	4	12.042 $^{m}/_{s}$	**8**	44	1.383 m
9	6	12.038 $^{m}/_{s}$	**9**	32	1.397 m
10	22	11.845 $^{m}/_{s}$	**10**	3	1.410 m
11	55	11.831 $^{m}/_{s}$	**11**	15	1.435 m
12	21	11.796 $^{m}/_{s}$	**12**	9	1.489 m
13	9	11.666 $^{m}/_{s}$	**13**	22	1.525 m
14	27	11.637 $^{m}/_{s}$	**14**	27	1.537 m
15	69	11.532 $^{m}/_{s}$	**15**	6	1.573 m
16	32	11.499 $^{m}/_{s}$	**16**	69	1.574 m
17	43	11.493 $^{m}/_{s}$	**17**	17	1.623 m
18	60	10.82 $^{m}/_{s}$	**18**	60	1.811 m
Mean		**11.914 $^{m}/_{s}$**	**Mean**		**1.445 m**

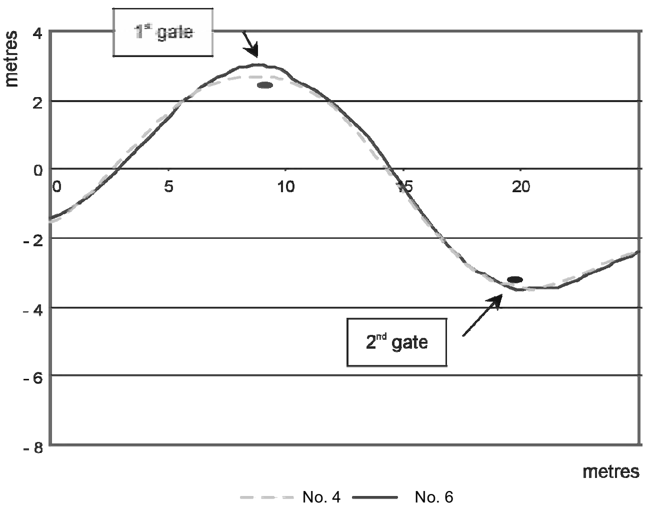
Legend:
Vavg → average velocity of the competitor in the measured segment (v $^{m}/_{s}$)
line/AVG → average value of the distance of the line of skiing (from the y-axis) in the measured segment (in metres)

Table 5. Calculation of the correlation of average velocities and average values of the length of two turns in the measured segment of the course in the 2004 Vitranc Cup competition

Correlation		Distance at the 1st and the 2nd pole
Velocity/AVG and line/AVG	Pearson Correlation	-.551*
	Sig. (2-tailed)	.018
	N	18

* Correlation is significant at the 0.05 level (2-tailed).

Legend:
velocity/avg → calculated values of the correlation coefficient and statistical significance of velocities in the measured segment
line/AVG → calculated values of the correlation coefficient and statistical significance of the distance of the line of skiing in the measured segment
Pearson Correlation → value of the correlation coefficient
Sig. (2-tailed) → statistical significance of the correlation coefficient
N → number of test subjects



Graph 1. Comparison of the lines of skiing of competitors Nos. 4 and 6.

Discusion and conclusion

As obvious from Tables 4 and 5, and Graph 1, we were also interested in what was going on with the velocity of skiing in the measured space. The fundamental question can be raised whether top competitors who ski nearer to the pole with a more direct, i.e. shorter, line also reach higher velocities.

A competitor whose line of skiing is more direct at the entry into a turn probably retains the velocity of skiing to a greater extent or he/she may even increase it. In this case an optimum direction of sliding can be retained only by a physically strong competitor with a perfect technique. Quick changing and angling of edges as well as steering the skis as directly as possible towards the next gate makes a shorter line of skiing from gate to gate possible (Matijevec, 2003, p. 70). Consequently, the velocity and shorter line of skiing cause increased pressure on skis in the phase of making a turn. If a competitor finds the pressure too strong, he/she must adjust (decrease) the velocity of skiing. Whenever he/she fails to do it, he/she must "correct"the selected line of skiing as soon as he/she reaches the next gate.

Our aim was to find out the average velocities reached by competitors in the measured space. Therefore average velocities that were reached were calculated for each competitor based on velocities reached at the first and the second poles as well as when they changed edges. Simultaneously, we tried to establish whether the average velocity of competitors who ski along a shorter line of skiing is higher than the velocity of competitors who choose a longer line of skiing.

Does a shorter line of skiing ensure faster skiing among the gates?

A shorter line of skiing means a shorter distance or a shorter route of a skier from one gate to another (in the measured space) and is an important factor when studying the skiing technique. Skis with a pronounced side curve enable competitors to make turns on edges. The condition that has to be satisfied if a competitor wants to start a turn in an optimum way is unweighting and quick changing of edges, angling of edges and steering the skis into a new turn. Here, it has to be mentioned that greater centripetal acceleration is achieved by means of a shorter line of skiing at the same velocity (Žvan, 1997, p. 57). A modern competitive technique and shorter skis with a more pronounced side curve make this possible. We have to be aware of the fact that in making such turns, friction between the skis and the snow is increased, which results in a greater reduction in velocity in the final part of the turn. Therefore we are faced with the dilemma of which manner of steering skis through the turn is faster and consequently more successful in the competitive alpine skiing (Lešnik, 1999, p. 28).

It is evident from the results (Table 4) that competitor No. 15 reached the highest velocity (12.535 m/s) in the measured segment. But as many as 10 competitors skied with a shorter line (1.435 m) in the measured space in comparison to the line of competitor No. 15. The shortest route between the two poles was that of competitor No. 4 (1.267 m), although the same competitor was placed eighth (12.042 m/s) if we take into account the average velocity of sliding within the measured space. Competitor No. 10 is a typical example of fast skiing with the shortest line. He reached the second highest average velocity (12.403 m/s) in the measured space; at the same time, he only slightly lagged behind the first competitor (No. 4) in the distance of the line (1.268 m). Competitor No. 60 was the slowest (10.820 m/s) to cover the measured segment and he also made the longest line (1.1811 m). Based on the findings, it can be concluded that individuals can ski faster or the fastest along a shorter or the shortest line (competitor No. 10); on the other hand, competitors whose lengths of lines of skiing exceeded the calculated average (1.445 m) skied, as a rule, through the measured segment with the lowest average velocities.

The average value of the distance of lines of skiing (in both turns) from the fall line (y-axis = 0) of all the competitors amounts to 1.445 m. Table 4 shows that the value of the line of skiing of the fastest competitor (No. 15) was close to the average (1.435 m). A lower value of the distance of the line of skiing from the fall line (y-axis) than that of the average (1.445 m) can be observed in seven competitors (Nos. 9, 22, 27, 6, 69, 17, and 60). It has to be stressed that according to the average velocity, all the above-mentioned competitors finished below the 9th place (No. 6). It is clear from Table 4 that as many as seven (Nos. 15, 10, 3, 2, 5, 44, 4) out of the fastest eighth competitors had a line of skiing shorter than the average (1.445 m).

If we go back (Tables 1 and 2), the sample of test subjects proves that the shortest line of skiing right at the pole does not ensure the optimum entry into the next turn. Table 4 shows that competitors with lines of skiing shorter than the average ones covered the measured segment with different velocities. According to the length of lines of skiing (average distance from y-axis = 0), "only" seven out of the first eleven competitors covered the measured segment with a velocity higher than the average (Nos. 4, 10, 2, 5, 44, 3, and 15).

Interestingly, the fastest competitors (Nos. 15 and 10) covered the measured space using the routes of different lengths. The average distance of the line of skiing of competitor No. 10 (from y-axis = 0) was shorter than the distance of the line of competitor No. 15 by as much as 0.167 m (Table 4). competitors Nos. 4 and 6 provide an even better example of the same velocity but a quite different line of skiing. They covered the measured space with practically the same average velocity (No. 4 = 12.042 m/s, No. 6 = 12.038 m/s), whereas their lines of skiing are quite different as far as the lengths (No. 4 = 1.267 m, No. 6 = 1.573 m) and the courses are concerned. The shortest line of skiing of all the competitors was that of competitor No. 4; his line of skiing was shorter than the average length of competitor No. 6 by as much as 0.306 m. Graph 1 shows mainly the difference in the first turn where competitor No. 6 skied at a greater distance from the pole than competitor No. 4 (Table 1). The rest of the line of skiing is similar in both competitors with the exception of the last turn. In spite of an obviously longer line of skiing, competitor No. 6 reached a similar velocity as competitor No. 4 (Table 4).

As regards the previously mentioned comparisons and results presented in Table 4, we also wanted to find out whether the correlation between the average velocity of skiing and the average distance of the length of the line of skiing from the y-axis in the whole measured segment is statistically significant.

In Table 5 the correlation coefficient (Pearson's correlation coefficient=– 0.551) proves that the correlation between the average velocity of skiing and the average distance of the length of the line of skiing from the y-axis in the whole measured segment is statistically significant (Sig.=0.0018). It has to be pointed out that this is a calculation of the data obtained in two slalom turns skied by competitors using a more or less direct line and reaching particular average velocities. In the measured sample (N=18), the length of the line of skiing in the whole measured segment (in two successive slalom turns) is correlated with the velocity of skiing in a statistically significant way, which means that the competitors with a smaller average distance from the y-axis in the pole setting (shorter line) reached higher average velocities as a rule. On the other hand, the average velocities of competitors with longer average lines of skiing were lower. It can be concluded that on the basis of an empirical analyse a shorter and more direct line of sliding increases the likelihood of reaching higher velocities and consequently better results. Whether skiing in such a way is possible through the whole pole setting and not only through a particular segment still remains an open question.

The development of the top skiing technique has long required the competitors to possess various skills. Therefore achieving good results in modern competitive alpine skiing is conditioned – apart from other dimesions of a psychosomatic status – mainly by top technical and tactical skills. These skills are based on the thoughtful and detailed planning and carrying out of a process of transformation, which demands a scientific basis within individual age groups in alpine skiing (Haymes & Dickinson, 1980, p. 154).

In the analysis, the segment of skiing skills has been analysed which may be considered the most important in the whole equation of the specification of success. This refers to the special technical and tactical aspects of making a modern slalom turn; these aspects are directly connected with higher or lower efficiency in top alpine skiing. In solving problems in sport it is difficult or even impossible to deal with the various aspects; that is the reason why we focused only on the part of a movement technique that is in the process of coaching closely connected with the tactics used in competition; in skiing as well as probably in other sports they are often of crucial importance (Supej & Černigoj, 2006, p. 60).

In practice coaches and competitors believe that a shorter line of sliding is also the fastest one in alpine skiing. This statement is simple and logical but only if we disregard the fact that the velocity in the turn on skis depends on several factors. When decreasing the length of the radius of a turn the skier's velocity can increase to a borderline and often critical level which still enables the skier to make a turn (using edges). How to choose a line of skiing in a particular pole setting depends on the technical and tactical skills, ability, equipment, and numerous other laws (of biomechanics), but the velocity is the factor which conditions the time achieved by a competitor. The limits of the ability to cover the course in a particular pole setting are certainly the highest in competitors who take part in the World Cup competitions (Božič, 2005, p. 42). That is why we tried to find the answers to our fundamental questions from these competitors.

The results obtained in the study would certainly be more objective if it had been possible to measure the whole pole setting in the given conditions (World Cup competition). Unfortunately, this is not possible at this moment due to technical and organizational problems. Nevertheless, we managed to obtain some results in a relatively small measured space. These results at least generally prove the orientation towards the coaching of a slalom technique, searching for a possibility of a more direct entry into and performance of a turn. However, it was observed a long time ago that an individual who manages to unite the individual segments of the pole setting into a whole in the best way is successful in a competition. Top technical skills do not bring success without the appropriate tactical abilities.

A competitor's feelings should represent feedback which would show when she/he skied fast and above all how she/he skied. It is important that a competitor learns how to recognize when she/he skis really fast and when and how she/he should accelerate in a particular pole setting. Today, the difference between a good and the best skier in the World Cup is extremely minor. Therefore it is the selection of the line of skiing through the segment of the length analysed in our study that is an important and often also decisive factor on the basis of which it can be established who will be "only"a good alpine skier and who the best one.

The aim of the study was to research critically the area of tactics in competitive alpine skiing, since in our opinion this area is still relatively neglected and unknown. As has already been mentioned, minor differences can mean a wide discrepancy in the competitive successfulness of an individual competitor. It is essential to have a good knowledge of tactical elements necessary in each competition in order to be able to take advantage of all the possibilities of achieving a top result. Tactics is probably the area which is worst developed in this field and we should pay more attention to it. We believe that it is in this area that experts could really make an important contribution to alpine skiing. We wanted to present objectively the part of a coach's assessments and information that he/she shares with competitors and that are of the utmost importance to everyone. This is the assessment of the velocity of a competitor's skiing.

The difference between a competitor's and coach's perception, on the one hand, and the measured velocity of skiing, on the other, often results in incorrect guidelines in the development of a skier's skiing technique as well as of his/her tactics. Especially the latter is becoming a decisive factor in the differentiation between good and the best competitors. The space of quantity and the intensity of expanding training in the technical as well as the motor area is becoming narrower and narrower. This study therefore seems to be an important contribution to knowledge about and recognition of the correlation between the length of a line of skiing and the velocity of skiing. The research was carried out on the best skiers in the world, which makes it even more important. The findings may not apply to the youngest skiers or to all skiers, but they certainly represent guidance on the method of work in the area of skiing tactics that leads to top results.

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VRHUNSKI SLALOMAŠI – KINEMATIČKA ANALIZA PUTANJE I BRZINE SKIJANJA

Sažetak

Uvod

Današnji vrhunski natjecatelji u skijanju nastoje povećavati brzinu skijanja najkraćom mogućom padnom putanjom. Tako skijanje postaje zahtjevno i rizično, pa posljedično to ne mora biti pravi način za postizanje uspjeha. Uspjeh u utrci ovisi o mnoštvu čimbenika. Sa stajališta tehnike, dobar rezultat posljedica je najboljeg mogućeg odnosa između brzine klizanja skije i odabira optimalne putanje zavoja u odnosu na određenu konfiguraciju skijaških vrata (štapova), tj. u odnosu na stazu. Suvremeno je skijanje brže u zavojima. Cilj svakog natjecatelja je napraviti čitav zavoj na rubovima bez tzv. rotacije skija, što uvijek uzrokuje veće ili manje bočno otklizavanje. Rotacija skija u zavoju bila je tipična za skijanje starom tehnikom, no danas ona predstavlja smo metodu za kontrolu brzine u skijanju kroz vrata.

Ciljevi ovog istraživanja bili su:

- ispitati razliku u izboru putanje skijanja između pojedinih natjecatelja Svjetskog kupa i utvrditi udaljenost njihovih putanja skijanja od štapa (padne linije);
- ispitati da li natjecatelji koji biraju najkraću liniju skijanja između štapova postižu veće brzine, otklizavaju li brže između slalomskih vrata te postižu li, na kraju utrke, bolji rezultat.

Metode

Varijable. Karakteristike slalomske tehnike proučavane su na bazi kinematičkih mjerenja provedenih 2004. godine za vrijeme održavanja utrke Svjetskog kupa na Vitrancu, za natjecanja u slalomu u Kranjskoj Gori.

Ispitanici. Testni uzorak činili su najbolji alpski skijaši svijeta koji su se natjecali u Svjetskom kupu pod pokroviteljstvom FIS-a. Finalni uzorak ispitanika činilo je 18 natjecatelja koji su imali startne brojeve između 2. i 69. Samo oni koji su, sukladno procjenama eksperata, odskijali stazu bez ikakvih uočljivih odstupanja koja su mogla utjecati na rezultate mjerenja, uključeni su u završnu analizu.

Metode. Prikupljeni podaci obrađeni su na Institutu za šport Fakultete za šport u Ljubljani. Nakon provedene kinematičke analize, dobiveni podaci obrađeni su u okviru programskog paketa SPSS. Osim prosječnih vrijednosti ubrzanja pojedinih segmenata tijela, izračunati su koeficijenti korelacije između pojedinih varijabli koje su određene u skladu s postavljenim ciljevima.

Postupak. Na temelju izračuna trajektorija skija (aritmetičke sredine položaja gležnjeva), određen je za svakog natjecatelja položaj trajektorije najbliže štapovima prvih i drugih vrata. Na taj je način utvrđeno da li je udaljenost linije skijanja od štapova prvih i drugih vrata slična kod vrhunskih natjecatelja te ako nije, u kojoj se mjeri razlikuje.

Rezultati

Uz pomoć koeficijenata korelacije između udaljenosti od prvog štapa i udaljenosti od drugog štapa, utvrdili smo da li su udaljenosti linija skijanja promatranih natjecatelja od pojedinih štapova približno jednake. Dobili smo rezultate prema kojima su one putanje skijanja koje su bile bliže prvom štapu, u pravilu, bile udaljenije od drugog štapa i obratno.

Također nas je zanimalo što se događa s brzinom skijanja u prostoru mjerenja. Osnovno je pitanje bilo da li oni vrhunski natjecatelji koji skijaju bliže štapu direktnijom, tj. kraćom putanjom ujedno postižu i veća ubrzanja.

Natjecatelj čija je linija skijanja direktnija na mjestu ulaska u zavoj vjerojatno zadržava brzinu skija u većoj mjeri, a čak je može i povećati. U tom slučaju optimalni smjer otklizavanja može biti zadržan jedino ako se radi o fizički snažnom natjecatelju koji ima savršenu tehniku. Brze promjene rubljenja da bi se skije usmjerile, što je (iz)ravnije moguće, prema sljedećim vratima čine liniju skijanja između vrata najkraćom mogućom. Sukladno tome, brzina i kraća linija skijanja povećavaju pritisak na skije u fazi zavoja. Ako natjecatelj taj pritisak doživljava prejakim, on mora prilagoditi (smanjiti) brzinu skijanja. Ukoliko mu to ne uspije, on potom mora 'korigirati' odabranu putanju skijanja čim doskija do sljedećih vrata.

Naš je cilj bio utvrditi brzinu koju postižu skijaši natjecatelji u prostoru mjerenja. Prosječne brzine su izračunavane za svakog pojedinog natjecatelja na temelju brzine postignute na razini prvog (prvih vrata) i drugog (drugih vrata) štapa, kao i u trenutku promjene rubljenja. Istovremeno, pokušali smo utvrditi da li je prosječna brzina onih natjecatelja koji skijaju kraćom, izravnijom putanjom veća u odnosu na one koji odabiru dužu, manje izravnu putanju prolaska kroz vrata.

Koeficijenti korelacije pokazuju da je povezanost između prosječne brzine skijanja i prosječne udaljenosti linije skijanja od osi y na razini cijelog prostora mjerenja statistički značajna. Na ovom uzorku ispitanika, duljina linije skijanja je u cijelom prostoru mjerenja (znači, u dva sukcesivna zavoja u slalomu) statistički značajno povezana s brzinom skijanja, što znači da oni natjecatelji kod kojih je udaljenost putanje skijanja od osi y manja (kraća, izravnija linija skijanja) postižu u pravilu veću brzinu skijanja. S druge strane, prosječna brzina natjecatelja s dužom prosječnom linijom skijanja je niža.

Zaključak

Na temelju dobivenih rezultata u ovom empirijskom istraživanju moguće je zaključiti da kraća i izravnija linija skijanja povećava vjerojatnost postizanja veće brzine skijanja, a posljedično i bolji rezultat. Je li tako moguće skijati cijelom stazom ili samo nekim njezinim dijelom, ostaje otvoreno pitanje.