COMPARISON OF CENTRE OF MASS TRAJECTORIES IN MODERN GIANT SLALOM TECHNIQUES

Blaž Lešnik and Milan Žvan

Faculty of Sport, University of Ljubljana, Slovenia

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Abstract:

An analysis was made of the possibility of executing modern giant-slalom technique variants, and the differences between them, on a sample of seven elite athletes in a simplified competitive situation. The analysis of the selected runs showed that all the athletes were able to perform the turns in given conditions with both giant-slalom techniques – the technique with velocity control and the technique with velocity increase. The analysis of kinematic parameters was limited to the centre of mass (CM) trajectories. The differences were tested with a Student's *t*-test for dependent samples.

Statistically significant differences were obtained between the two skiing techniques in the athletes' CM trajectories in the measured area (second and third turns). This fact, together with other proven differences between the trajectories of both techniques, mostly contributed to the confirmation of the advantage of skiing with the technique with velocity increase and the realization of the theoretical and practical background of this study.

Key words: *alpine skiing, giant slalom, kinematics, competitive technique, differences*

VERGLEICH VON KÖRPERSCHWERPUNKT-FLUGBAHNEN IN MODERNEN RIESENSLALOM-TECHNIKEN

Zusammenfassung:

Es wurde in dieser Studie eine Analyse gemacht, sowohl von der Möglichkeit, unterschiedliche moderne Riesenslalom-Techniken durchzuführen, als auch von Unterschieden zwischen diesen Techniken. Diese Forschung wurde in vereinfachten Wettkampfbedingungen an sieben Hochleistungssportlern durchgeführt. Die Analyse von ausgewählten Läufen zeigte, dass alle Sportler die Skikenntnisse hatten, die Schwünge in beiden Riesenslalom-Techniken – die Technik, die die Geschwindigkeitskontrolle impliziert, einerseits und die Technik, die die Geschwindigkeitssteigerung impliziert, andererseits – durchführen zu können. Die Analyse von kinematischen Parametern wurde zur Analyse von Körperschwerpunkt-Flugbahnen begrenzt. Die Unterschiede wurden mittels der Studenten *t*-Test für abhängige Gruppen getestet. Die statistisch bedeutende Unterschiede zwischen den beiden Skitechniken zeigten sich in den Körperschwerpunkt-Flugbahnen von Sportlern innerhalb der gemessenen Strecke (der zweite und der dritte Bogen). Diese Tatsache, zusammen mit anderen bestätigten Unterschieden zwischen den Flugbahnen in beiden Skitechniken, trug dazu bei, sowohl es zu bestätigen, dass die Technik, die die Geschwindigkeitssteigerung impliziert, vorteilhaft ist, als auch die Realisation vom theoretischen und praktischen Hintergrund dieser Studie zu befürworten.

Schlüsselwörter: *Ski alpin, Riesenslalom, Kinematik, Wettkampftechnik, Unterschiede*

Introduction

Due to the complexity and variability of competitive conditions, the scientific research and study of problems in alpine skiing is very limited. Unstable conditions and also the differences between the athletes influence the motor structures and techniques of overcoming obstacles in alpine skiing. These are precisely the reasons why science required more time to implement a systematic and more precise definition of certain suppositions and facts that have never been completely proved up until now. It is in these findings based on primary postulates that we could find the dimensions and details which still hide the successfulness potential of elite alpine skiing in the future (Lešnik & Žvan, 1998; Raschner, 1997).

Modern skiing through the course gates connects the individual turn segments into a single action. It is therefore very difficult and also, at least in practice, unwise to study them separately. However, this is currently unavoidable in a theoretical analysis. Taking into consideration the high level of interwoveness of the motor action sequences of modern giant slalom turns, the competitive turn is divided into three phases (Žvan et al, 1996): a) turn entry phase, b) turn steering phase and c) turn completion phase.

Alongside all the other factors that affect the technique, the search for new, more efficient ways to ski through the gates is related above all to the control and increase of skiing velocity. The above-mentioned turn phases are typical for both skiing techniques that were used in the study.

Taking different skiing styles of competitors into account, we tried to limit ourselves to two primary combinations of motor structures when defining modern giant-slalom techniques (Lešnik, 1999):

- *Technique A with velocity control, which is an established giant-slalom technique*

This technique is characterized by a strong push-off in the turn and defined by a pronounced vertical movement. Consequently, the centre of mass is markedly moved away from the ground. The above-mentioned accelerated movement of the centre of mass (CM) from the ground leads to greater differences in the pressure on the ground. Besides increased air resitance, the latter causes the greatest hindrance in skiing.

- *Technique B with velocity increase*

The basic characteristic of technique B is to persist in a lower skiing position and in a reduced vertical movement of the centre of mass of a skier presupposing a different type of weighting and unweighting of skis; this has been called the lateral movement.

Both techniques were arbitrarily differentiated by means of video analyses made by six skiing experts. The experts monitored two essential characteristics of techniques and consequences of their application.

These are:

- the difference in the vertical movement of a competitor and his centre of mass and
- the deviation from the fall line.

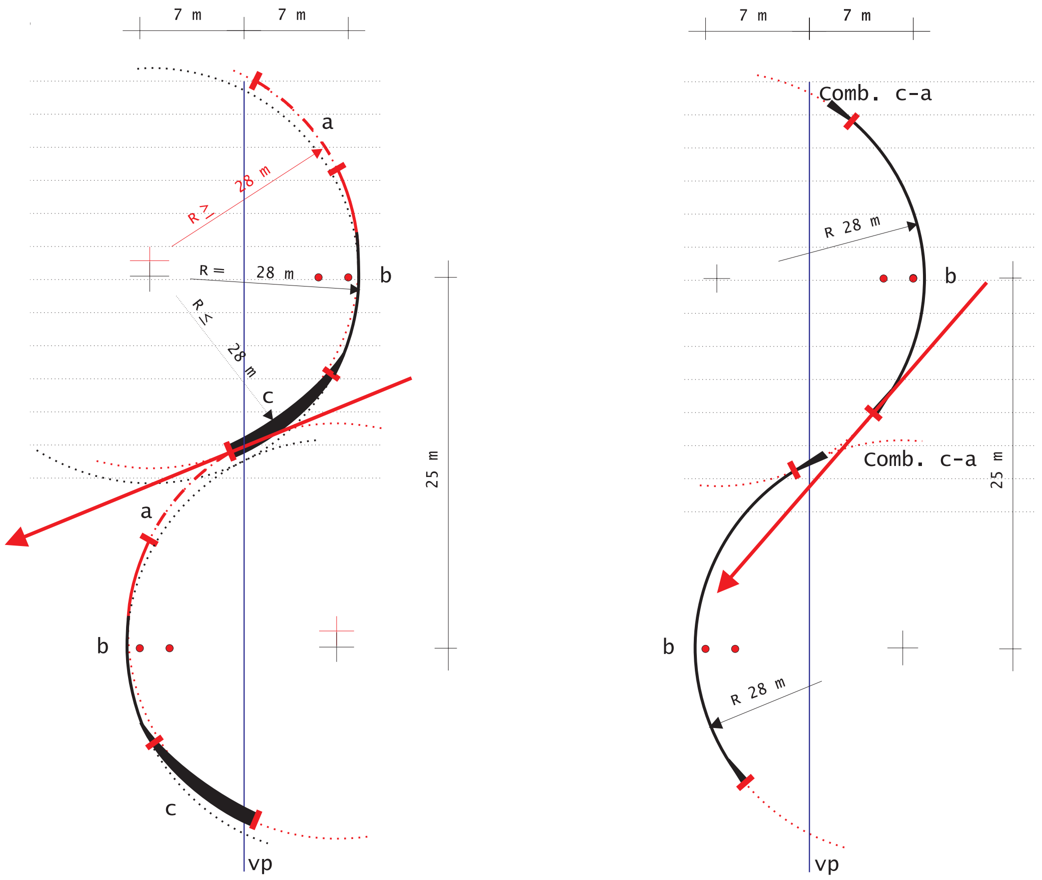


Figure 1. Graphical representation of a turn with velocity control technique - A (left) and velocity increase technique - B (right)

The technique with velocity increase (B) should be more suitable as regards our strivings for more efficient and especially faster skiing among the gates. The advantages in elements of the individual phases of technique B are also confirmed by the characteristics of motor structures of some elite competitors (Raschner et al., 1999).

The main reasons for the current, and probably also future, strivings for developing the technique for velocity increase (B) lie in the possibilities offered by the contemporary ski design and a better psychophysical preparation of athletes. Performing a turn without sliding as well as without lateral unweighting allows a skier to brake less while exiting the turn, followed by the transition to a new turn, which should be performed, if possible, without any (or with as little as possible) vertical movement. The main differences between the two skiing techniques (A and B) can be seen in certain sequences of the transition between two turns (Figures 2 and 3).

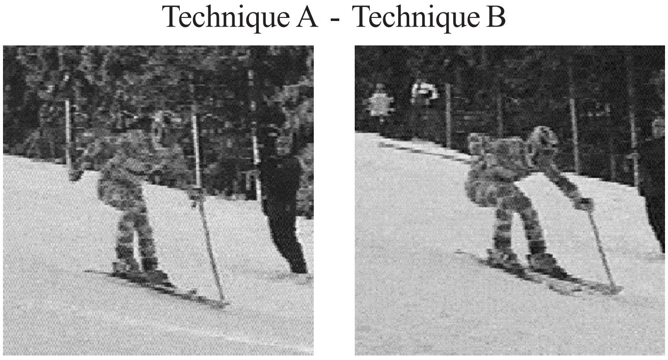


Figure 2. Direct comparison of techniques A and B - 21st picture of the 2nd turn segment

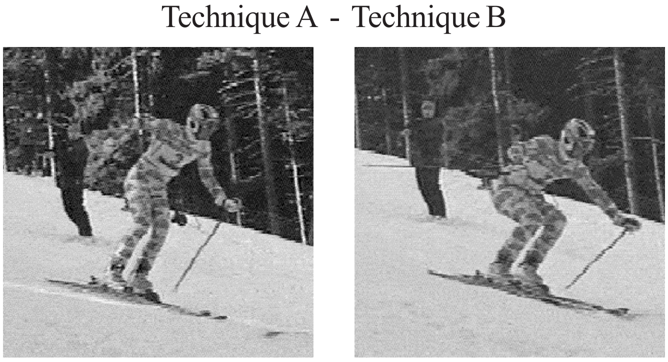


Figure 3. Direct comparison of techniques A and B - 30th picture of the 2nd turn segment

The principal goal of the modern skiing technique is to preserve velocity in all phases of the competitive turn, which means that as little velocity as possible should be lost. This can be achieved by the so-called lateral unweighting where in the turn completion phase (3rd phase) the knees and the skis are pulled under the body in the shortest possible time and pushed to the other side into a new turn (1st phase). In this way a minimal vertical movement of the centre of mass is performed and the pressure on the ground is reduced.

The aim of this is to achieve the quickest possible reduction of edging and transition to flatly placed skis directly oriented towards the next gate. The turn should be (theoretically) executed with the smallest possible radius and as close to the gate as possible. The skis should be on their edges for the shortest possible time between two turns (flat position) in order to achieve the least possible loss of gliding velocity (Rajtmajer & Gartner, 1987., Kugovnik at al., 1998). The mentioned experiments showed that the skiing velocity can increase when a ski is on its edges and appropriately bent (while performing a turn). Then outward forces (e.g. centrifugal force) act on a skier and they together with the activity of a competitor represent a higher velocity.

Methods

Sample of participants

Sample of participants consisted of elite seven male athletes (between twenty and twenty-five years of age) who are, or were recently members of the Slovene national competitive team in alpine skiing.

Measurement procedure

The measurements were performed on a homologated course with a gradient of 15 to 20 degrees, which allows the execution of skiing turns with both techniques. There was also sufficient approach space for a skier to achieve the required entry velocity (approx. 60 km/h) into the course. There were six rhythmically positioned giant-slalom gates, with a 7m distance perpendicular to the fall line (z-axis) and a distance of 27 m (x-axis) along the fall line. Two pairs of photocells (10 m apart) were placed 2 m before the entry into the course in order to establish immediately the entry velocity. All runs that did not match the preset entry velocity requirements were discarded; the same applies to the runs that did not conform to the two defined skiing techniques (A or B). In order to establish kinematic parameters, a video system for a 3D kinematic analysis APAS (Ariel Performance Analysis System) and CMAS (Consport Motion Analysis System) were used, but as far as the issues of this article are concerned, the measurement of the 2D kinematic space would suffice (x- and z-axes). The course was determined with two reference cubes and thus defined also with the horizontal x-axis, vertical y-axis and transverse z-axis. In the course of measurement, four pairs of cameras were used that were placed perpendicularly on the hard surface (eight cameras – 50 Hz and 50 photos per second, resolution 720x576, PAL standard). Seven competitors performed 84 runs altogether (each competitor performed six runs in technique A and six runs in technique B).

Sample of variables - kinematic parameters

ASTX0000	CM trajectory of technique A in x-axis after time: Sx(t)
ASTZ0000	CM trajectory of technique A in z-axis after time: Sz(t)
BSTX0000	CM trajectory of technique B in x-axis after time: Sx(t)
BSTZ0000	CM trajectory of technique B in z-axis after time: Sz(t)

Data analysis

On the basis of a precise overview of the videos and after discarding invalid runs, the selected sample of runs was obtained. Seven valid pairs of runs (with technique A and technique B), one pair of each of the seven observed athletes were used for further analysis.

The next phase was a computer acquisition of data and a transformation of video pictures into a digital form. Taking into account camera image resolution, as well as spatial relationships during measurement (see Measurement procedure), the digitization error may be estimated to ± 2%. A ten-segment model of the human body was used for digitalization, requiring fourteen points. These points represent the axes of the joints, tip of toes of the left and right foot, the first neck vertebra and the temple of the head. The CM was computed from the point co-ordinates (X, Y and Z) of the centres of gravity of the ten used body segments of the anthropometric model, defined by Dempster, via Miller and Nelson (Winter, 1990). The anthropometric characteristics of the competitors did not affect the performance of the experiment. In the course of the procedure, a competitor was compared with himself. In this procedure we monitored the CM trajectories, which, understandably, differed depending on the different anthropometric characteristics of the individuals. The same competitors used the same equipment during the measurement, which is limited and prescribed by the FIS (Federation Internationale de Ski – FIS, 1996). Individual parts of the equipment represented a hard and component part of each test subject.

The data were transformed according to the APAS 99 model. Data smoothing was performed with a "Digital 7" filter (low-pass filter with 7 Hz cutoff frequency), followed by a data analysis with a program recently developed with outside help at the Institute of Sport at the Faculty of Sport, University of Ljubljana. The filter mentioned enables us to adjust the photos gained in numerous individual phases of the turn to average values, which are more easily compared with the trajectory of the same competitor in the turn performed by means of the other technique. Digitalization is a common procedure which can be traced in the majority of analyses of kinematic parameters in monitoring the movement of the competitors in a variety of sports. The procedure presupposes a precise assessment of the operater concerning the position of the individual body parts of the competitor, since this assessment is decisive for the precision of the comparison of individual performances of the techniques in all the phases of the turn.

The statistical analysis of the kinematic parameters was made by means of the SPSS statistical package. Basic descriptive statistical parameters were computed, the differences between the two skiing techniques were tested with the Student's *t*-test for small dependent samples. We tried to prove that differences exist between the two techniques by comparing CM trajectories in the most important time intervals of the turns.

Results

Comparison of CM trajectories of both techniques on the x-axis

In order to achieve a better overview of the whole, that is two consecutive turns we analysed the computed values according to groups of time-sequenced variables. It should also be said that when dealing with very small samples, one might also consider the absolute values of the *t*-value (for example those that exceed 2.0) and not just base the interpretation on the statistical significance (usually set at $p<0.05$) of the parameter. If the differences remained the same, a value of $t=2.0$ would be statistically significant for a larger subject sample.

The differences are statistically significant in the section where the turn steering phase (b) is prolonged in technique B and where we have the turn completion phase (c) in technique A. From this point on there are no statistically significant differences in the CM trajectories between the two techniques, mostly due to the larger absolute values that are compared. Besides the statistically significant differences, we were also interested in the actual differences between averages of the path travelled in the analysed techniques. The final analysis showed a considerable advantage of the runs performed with technique B (88 cm). Since we performed the measurements of the kinematic parameters only for the second and third turns of the complete course, the summation of such differences can mean a considerable advantage of skiing with technique B at the finish (Table 1).

Table 1 shows the comparison of variables representing the movement of CM of the skier on the x-axis of the coordinate system. On the basis of the computed values we can determine the distance travelled (in metres) the subjects covered on average in a certain period of time (in seconds) from the fall line (x-axis).

Comparison of CM trajectories of both techniques on the z-axis

The CM trajectories on the z-axis of the coordinate system show the deviation of the measured subject sample from the horizontal z-axis. This represents a deviation of CM from the fall line which is supposed to be minimal in conditions set by the gates placings. The computed values of the path of CM according to the z-axis represent the average distance travelled of CM (in metres) in a direction lateral to the fall line. At first the presented values are therefore negative, but after passing the "0 point" on the z-axis, they become positive.

When comparing the CM trajectories of the two skiing techniques on the z-axis, the results do not show statistically significant differences in their deviation from the fall line (x-axis). Because of the small absolute measured values the obtained parameter values are expected; so it was more interesting to compare directly the average values of the monitored variables. This comparison leads us to significant findings, connected to a section in

Table 1. Comparison of CM trajectories in techniques A and B on x-axis in chosen sections

Variable	$\overline{X}$ ***(A)***	$\overline{X}$ ***(B)***	**SD** *(A)*	**SD** *(B)*	***t***	***p(t)***
…						
STX0008	1.8936	1.8846	.06273	.1033	.273	.794
…						
STX0020	3.7371	3.7604	.1192	.1491	-.696	.512
STX0022	4.0316	4.0600	.1309	.1553	-.804	.452
STX0024	4.3236	4.3569	.1429	.1605	-.882	.412
STX0026	4.6127	4.6513	.1558	.1658	-.944	.381
STX0028	4.8997	4.9446	.1686	.1715	-.997	.357
…						
STX0066	10.2367	10.4371	.2550	.2607	***-2.190***	.071
STX0068	10.5289	10.7341	.2585	.2618	***-2.200***	.070
STX0070	10.8199	11.0297	.2635	.2630	***-2.191***	.071
STX0072	11.1096	11.3246	.2706	.2643	***-2.169***	.073
STX0074	11.3983	11.6191	.2793	.2655	***-2.146***	.076
STX0076	11.6859	11.9123	.2880	.2669	***-2.121***	.078
STX0078	11.9721	12.2036	.2946	.2678	***-2.097***	.081
STX0080	12.2579	12.4926	.2995	.2684	***-2.065***	.084
STX0082	12.5433	12.7809	.3028	.2697	***-2.035***	.088
STX0084	12.8286	13.0693	.3065	.2711	***-2.003***	.092
STX0086	13.1137	13.3581	.3113	.2730	-1.976	.096
STX0088	13.3974	13.6470	.3179	.2748	-1.958	.098
STX0090	13.6816	13.9361	.3267	.2770	-1.932	.102
STX0092	13.9659	14.2264	.3369	.2790	-1.909	.105
STX0094	14.2519	14.5173	.3480	.2803	-1.877	.110
STX0096	14.5396	14.8089	.3596	.2818	-1.835	.116
STX0098	14.8283	15.1011	.3711	.2839	-1.793	.123
STX0100	15.1174	15.3939	.3831	.2867	-1.751	.130
…						
…						
STX0120	18.3207	18.8369	.7383	.4325	-1.789	.124
STX0122	18.6811	19.2114	.7619	.4427	-1.788	.124
STX0124	19.0467	19.5849	.7769	.4542	-1.777	.126
STX0126	19.4153	19.9589	.7890	.4666	-1.764	.128
STX0128	19.7837	20.3334	.8044	.4793	-1.753	.130
STX0130	20.1504	20.7070	.8249	.4926	-1.743	.132
STX0132	20.5173	21.0791	.8484	.5064	-1.727	.135
STX0134	20.8854	21.4514	.8732	.5215	-1.707	.139
…						
STX0148	23.5087	24.1236	1.0709	.6478	-1.616	.157
STX0150	23.8869	24.5069	1.0987	.6643	-1.607	.159
STX0152	24.2651	24.8913	1.1263	.6822	-1.601	.161
STX0154	24.6443	25.2781	1.1548	.7022	-1.596	.162
STX0156	25.0249	25.6684	1.1847	.7245	-1.593	.162
STX0158	25.3764	26.0291	1.1601	.6902	-1.590	.163
STX0160	25.7494	26.4094	1.1682	.6898	-1.583	.164
…						
STX0176	28.7183	28.8589	1.2721	1.0832	-.293	.779
STX0178	29.0510	29.4987	1.3537	.8278	-.717	.500
STX0180	29.4214	30.1283	1.3706	.6339	-1.370	.220
STX0182	29.7901	30.4933	1.3869	.6292	-1.347	.227
STX0184	30.1576	30.8586	1.4022	.6259	-1.329	.232
STX0186	30.5237	31.2240	1.4151	.6242	-1.315	.237
STX0188	30.8884	31.5891	1.4258	.6239	-1.304	.240
…						
STX0200	33.0411	33.9203	1.4657	.4699	-1.637	.153
…						

Legend: $\overline{x}$ (A) - average value of variable in technique A, (B) - average value of variable in technique B,
SD (A) - standard deviation technique A, SD (B) -standard deviation technique B, *t* – *t*-test,
p(t) - statistical significance of *t*-test

the transition between the two measured turns. The results show a smaller deviation of CM in technique B than in technique A and, therefore, a more direct path towards the next gate (Table 2).

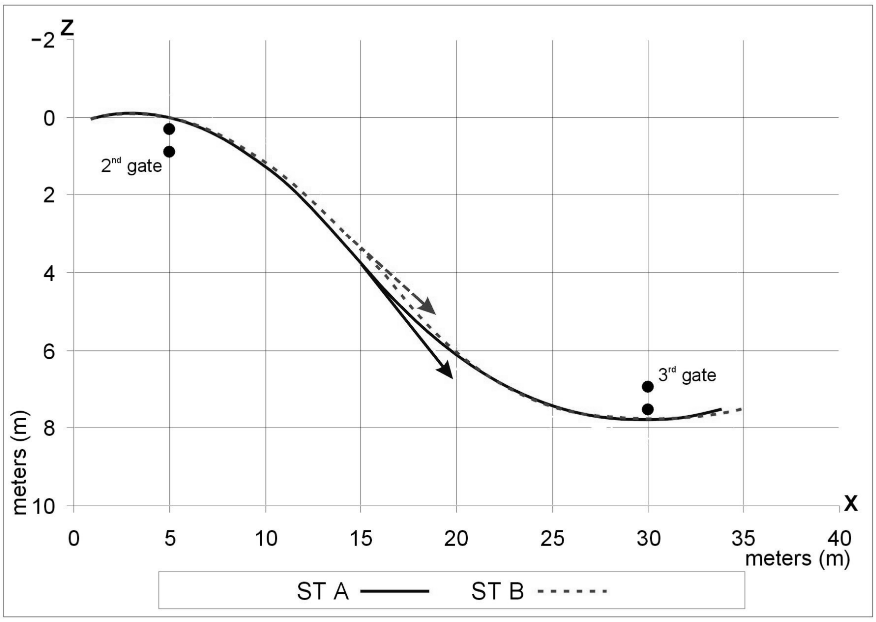
Table 2. Comparison of CM trajectories in techniques A and B on z-axis at certain instants

Variable	$\bar{X}$ (A)	$\bar{X}$ (B)	SD (A)	SD (B)	t	p(t)
...						
STZ0008	-.1101	-.051143	.2664	.2060	-.714	.502
...						
STZ0020	-.1294	-.062714	.1832	.2141	-.778	.466
STZ0022	-.1087	-.039857	.1747	.2197	-.790	.460
STZ0024	-.081429	-.011571	.1676	.2266	-.783	.463
STZ0026	-.047429	.02214	.1602	.2335	-.763	.474
STZ0028	-.060000	.06229	.1535	.2406	-.731	.492
...						
STZ0066	1.2384	1.2199	.1656	.1315	.380	.717
STZ0068	1.3464	1.3216	.1820	.1371	.478	.650
STZ0070	1.4607	1.4287	.1977	.1413	.578	.584
STZ0072	1.5807	1.5423	.2126	.1456	.648	.541
STZ0074	1.7056	1.6614	.2260	.1497	.696	.513
STZ0076	1.8341	1.7851	.2387	.1536	.723	.497
STZ0078	1.9660	1.9127	.2512	.1564	.738	.488
STZ0080	2.1000	2.0427	.2629	.1585	.752	.480
STZ0082	2.2357	2.1740	.2745	.1606	.769	.471
STZ0084	2.3730	2.3073	.2868	.1645	.779	.466
STZ0086	2.5117	2.4423	.2994	.1699	.785	.463
STZ0088	2.6533	2.5807	.3118	.1760	.783	.463
STZ0090	2.7971	2.7223	.3226	.1806	.773	.469
STZ0092	2.9434	2.8670	.3315	.1825	.758	.477
STZ0094	3.0904	3.0123	.3380	.1824	.757	.478
STZ0096	3.2371	3.1569	.3445	.1819	.762	.475
STZ0098	3.3829	3.3001	.3523	.1841	.773	.469
STZ0100	3.5286	3.4444	.3615	.1880	.771	.470
...						

Variable	$\bar{X}$ (A)	$\bar{X}$ (B)	SD (A)	SD (B)	t	p(t)
...						
STZ0118	5.1806	4.955	.6270	.5061	.631	.551
STZ0120	5.3603	5.576	.6299	.8365	-.973	.368
STZ0122	5.5351	5.730	.6337	.8612	-.893	.406
STZ0124	5.7000	5.881	.6442	.8777	-.837	.435
STZ0126	5.8561	6.026	.6571	.8882	-.794	.458
STZ0128	6.0069	6.167	.6681	.8942	-.751	.481
STZ0130	6.1536	6.304	.6741	.8958	-.707	.506
STZ0132	6.2949	6.436	.6759	.8924	-.669	.529
STZ0134	6.4296	6.565	.6741	.8829	-.647	.542
...						
STZ0148	7.1760	7.304	.6081	.7067	-.770	.470
STZ0150	7.2566	7.385	.5860	.6703	-.807	.451
STZ0152	7.3297	7.461	.5623	.6300	-.862	.422
STZ0154	7.3967	7.533	.5360	.5866	-.931	.388
STZ0156	7.4570	7.598	.5083	.5421	-1.004	.354
STZ0158	7.5203	7.665	.4890	.5036	-1.073	.324
...						
STZ0184	7.7289	7.778	.3564	.1761	-.499	.635
STZ0186	7.7199	7.771	.3681	.1674	-.485	.645
STZ0188	7.7096	7.759	.3782	.1593	-.453	.667
...						
STZ0200	7.5743	7.583	.4031	.1214	-.072	.945

Legend: same codes as in Table 1

Comparison of CM trajectories of both techniques in the XZ-plane



Legend: ST A - trajectory of CM: technique A (uninterrupted line), ST B - trajectory of CM: technique B (dotted line)

Graph 1. Representation of CM trajectories of techniques A and B in XZ-plane

Graph 1 shows the differences between techniques A and B in the CM trajectories in the XZ-plane. The main point we are trying to present graphically is related to the movement of CM in the XZ-plane in two connected giant-slalom turns. In the turn steering phase (b) we can see that both CM trajectories practically overlap, from the time of entry into the measured area to the passing through the gate.

The largest differences in the trajectories can be noticed in the area that is approximately 10–20 m from the x-axis and 1–6 m from the z-axis (values of variables from STX0066 to STX0128 – Table 1, and from STZ0066 to STZ0128 – Table 2). These differences between the two techniques concern mainly the different direction of movement as seen from the next gate. Technique B gives an exit-direction more oriented towards the next gate. This is represented in Graph 1 as arrows, showing the direction of CM towards the next gate, which is made possible by the technique used. These differences in direction (arrows) are also the consequence of the transition into the turn completion phase (c) in technique A; that is why the prior turn steering phase (b) is shortened. In technique B, however, the turn steering phase (b) is prolonged because of the more direct gliding in the direction of the next gate, followed by a quicker transition into the “c-a” combination phase.

The consequence of a prolonged turn steering phase (b) and a faster transition into the “c-a” combination in technique B in a section after 20 m from the x-axis (from variable STX0130 on – Table 1) and after 6 m from the z-axis (from variable STZ0130 on – Table 2) is seen as a resumed overlap of the CM trajectories of both techniques. This is also marked with the entry into the turn steering phase (b) in technique B, which begins earlier (edging – Graph 4) than in technique A. The two (technique A and technique B) CM trajectories almost overlap in the mentioned section.

After exiting the gate, i.e. in the section after 30.8 m from the x-axis (variable STX0188 in Table 1) and 7.7 m from the z-axis (variable STZ0188 in Table 2), we can see the beginning of the transition into the turn completion phase (c) for technique A and the prolongation of the turn steering phase (b) for technique B. The direction of CM in technique B is again better oriented towards the next gate (Graph 1).

Conclusion

Up until now the choice of technical and tactical elements in alpine skiing has been left to the momentary intuitive choices of an individual (Petrovič, Smitek, & Žvan, 1983). Doubtless, these choices play the greatest role, but are often insufficient. In future, the training process should, therefore, be more oriented towards perfecting the competitive skiing technique in various situations and conditions, making the use of the most modern measurement methods unavoidable.

When commenting on the comparison of CM positions on the x- and z-axes, we always considered the differences in the trajectories of both techniques. In the light of the problem under consideration, these differences are best shown in the XZ-plane. The two considered skiing techniques do not have the same direction of CM movement in a certain segment of the transition between the two measured turns (Graph 1).

In elite alpine skiing a precise study of the technique of motor action should be based on determining the kinematic parameters necessary to define precisely the position of certain points and body segments in time and space. On the basis of the determined trajectories and other kinematic parameters of the body points in certain skiing segments that are important, we can analyse precisely the executed movement segments which are used to define the skiing technique. We can also determine the differences between skiing techniques and consequently the efficiency of the techniques.

On the basis of the results of this study we can only presuppose the possibilities of changing the gliding technique in various circumstances. At higher velocities on steeper courses, especially for the “closed course settings”, it is still more likely that elements with velocity control (A) will dominate. It is very difficult to say where the limits are, where an earlier reduction of edging and gliding more directly in the direction of the next gate is possible, since it is also individually defined.

The goal set in this study was to compare two different competitive techniques (A and B). It has been assessed that the data and the results obtained enabled us to describe the characteristics of both techniques and to present simultaneously the advantages of technique B, which, we believe, will be the prevalent one in the future. This means that even in more difficult circumstances the competitors will ski in the lower skiing position and in all circumstances they will unweight and weight their skis in the course of transition from one turn to another in a lateral way. This is, of course, not exclusively the problem of mastering the skiing technique, but rather the problem of a better psychophysical condition of the competitors.

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Correspondence to:
Prof. Blaž Lešnik, Ph.D.
University of Ljubljana, Faculty of Sport,
Gortanova 22, SI-1000 Ljubljana, Slovenia
Phone: +386 1 520-77-00 (institution) or
GSM: +386 41 408-515 (personal)
Fax: +386 1 540-22-33
E-mail: blaz.lesnik@sp.uni-lj.si

USPOREDBA TRAJEKTORIJA TEŽIŠTA TIJELA U MODERNIM VELESLALOMSKIM TEHNIKAMA

Sažetak

Uvod

Moderna skijaška vožnja između vrata spaja pojedinačne elemente sijaškog zavoja u jedinstveno kretanje, pa ih je vrlo teško, barem u praksi, proučavati odvojeno. Ipak, to je neizbježno u suvremenoj teorijskoj analizi. Uzmemo li u obzir visok stupanj isprepletenosti sekvencija motoričkog gibanja u izvedbi sastavnih elemenata moderne tehnike veleslalomskog zavoja, natjecateljski bismo zavoj mogli podijeliti na tri faze (Žvan i sur., 1996):

a) faza ulaska u zavoj,
b) faza vođenja zavoja i
c) završna faza zavoja.

Uzevši u obzir specifičnosti pojedinih skijaških tehnika individualnih natjecatelja, pokušali smo se u definiranju moderne veleslalomske tehnike skijanja ograničiti na dvije primarne kombinacije motoričkih struktura (Lešnik, 1999.):

- tehnika koja podrazumijeva kontrolu brzine (A) - uobičajena veleslalomska tehnika koju karakterizira snažan odraz u zavoju, a definirana je izrazitim vertikalnim gibanjem;
- tehnika koja podrazumijeva povećanje brzine (B) - osnovna joj je karakteristika zadržavanje niskog skijaškog položaja i smanjeno vertikalno gibanje težišta tijela, što pretpostavlja raznoliko opterećivanje i rasterećivanje skija, a naziva se lateralno gibanje.

Šest skijaških eksperata usporedilo je dvije tehnike na temelju video analiza, a odbačeni su neuspjeli pokušaji. Eksperti su procjenjivali tehničke osobitosti pojedine tehnike, kao i rezultate primjene svake od njih.

Osnovni cilj modernih natjecateljskih skijaških tehnika jest zadržati brzinu u svim fazama izvedbe zavoja ili, drugim riječima, ostvariti što manji gubitak brzine. To se može ostvariti tzv. lateralnim rasterećenjem gdje se u završnoj fazi zavoja (3. faza) koljena i skije, u što je moguće kraćem vremenu, podvlače pod tijelo i guraju u suprotnu stranu u sljedeći zavoj (1. faza zavoja). Na taj se način postiže minimalno vertikalno gibanje težišta, a pritisak na snježnu podlogu je smanjen.

Cilj je ovog istraživanja bio usporediti položaj trajektorija težišta tijela za vrijeme izvedbe zavoja veleslalomskim skijaškim tehnikama A i B.

Metoda

Mjerenje je provedeno na homologiziranoj stazi gradijenta od 15 do 20 stupnjeva, što omogućava izvođenje skijaških zavoja objema tehnikama. Također je bilo dovoljno pristupnog prostora za postizanje potrebne ulazne brzine (od oko 60 km/h) u stazu. One vožnje u kojima nije postignuta potrebna ulazna brzina za izvedbu zavoja, nisu bile analizirane, a isto tako nisu analizirane ni izvedbe zavoja koje nisu bile u skladu sa zahtjevima dviju definiranih skijaških tehnika (A ili B).

Na temelju preciznog pregleda video snimaka i nakon izbacivanja nezadovoljavajućih izvedaba, odabran je uzorak vožnji. Sedam valjanih parova vožnji (tehnikom A i tehnikom B) koje je odvozilo sedam skijaša (u dobi između dvadeset i dvadeset pet godina), članova elitnog slovenskog natjecateljskog tima alpskih skijaša, korišteno je u daljnjoj analizi.

Sljedeća faza bila je kompjutersko prikupljanje podataka i transformacija video snimaka u digitalni format. Za digitalizaciju je uporabljen desetosegmentni model ljudskoga tijela, a korišteno je 14 točaka. Tim smo postupkom pratili trajektorije težišta tijela (CM), koje su se, razumljivo, razlikovale ovisno o različitim antropometrijskim karakteristikama skijaša.

Rezultati

Statistička analiza kinematičkih parametara učinjena je pomoću SPSS statističkog paketa. Izračunati su parametri deskriptivne statistike, a zatim su razlike između dvije skijaške tehnike izračunate pomoću Studentovog *t*-testa za male zavisne uzorke. Kako bismo postigli bolji uvid u analizirane zavoje, analizirali smo i izračunate vrijednosti u odnosu na vremenske sekvencije varijabli. Razlike po osi x statistički su značajne u dijelu u kojem se produžava faza vođenja zavoja (faza b) u tehnici B te u dijelu završne faze zavoja (faza c) u tehnici A. Završna analiza pokazala je znatnu prednost voženja B tehnikom (88 cm). Usporedbom trajektorija CM dviju skijaških tehnika po osi z nisu dobivene statistički značajne razlike u otklonima od padne linije (os x). Rezultati pokazuju manja odstupanja trajektorija CM u tehnici B, kao i izravnije kretanje prema sljedećim vratima.

Glavni nalaz, koji smo pokušali prikazati grafički (graf 1), odnosi se na kretanja trajektorija CM u ravnini XZ u povezanoj izvedbi dva veleslalomska zavoja. Najveće razlike trajektorija

vidljive su u području otprilike 10-20m od osi x i 1-6m od osi z. Te razlike između tehnika A i B odnose se uglavnom na različit smjer kretanja prema sljedećim vratima: tehnika B daje izlazno-usmjereno kretanje koje je više usmjereno prema sljedećim vratima. Te razlike u smjerovima (strelice) također su posljedica prelaska u završnu fazu zavoja (faza c) u tehnici A, zbog čega dolazi do skraćivanja faze vođenja zavoja (faza b). U tehnici B, međutim, faza vođenja zavoja (b) produžena je zbog izravnijeg kretanja u smjeru sljedećih vrata, što je popraćeno bržom promjenom u kombinaciju faza ‘c-a’.

Zaključak

Cilj je ovog istraživanja bio usporediti različite natjecateljske tehnike (A i B). Procjenjujemo da nam podaci, kao i dobiveni razultati omogućuju opis karakteristika obiju tehnika, a istodobno i prednosti tehnike B za koju vjerujemo da će prevladati u budućnosti. To znači da će, usprkos težim uvjetima, skijaši skijati u nižoj poziciji, a općenito će rasterećivati i opterećivati svoje skije u vožnji pri prijelazu iz jednoga u drugi zavoj na lateralan način. To, naravno, nije isključivo problem usavršavanja skijaške tehnike, već je to u većoj mjeri vezano uz bolju psihofizičku kondiciju natjecatelja.