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SITUATIONAL BIOMECHANICAL PARAMETERS AT SLALOM CARVING SKIS IN TOP LEVEL SKIERS

INTRODUCTION

In a past years biomechanical investigations were oriented towards determination of kinematical parameters (time-space), dynamical parameters (force of ground reaction) as well as the situational parameters which enable the defining of the computerized simulation (training apparatus, simulators), and also the possibility of the movement structure determination through the animation.

Based at the past investigations of the skiing technique it is noticeable that more often they were the investigations of the kinematical parameters, facilitating the choice of the best body positions and certain body segments in space and time. Influence of the new skis technology (carving model) is noticeable during last years.

Realization of the biomechanical analysis of the sports technique in top level athletes is far less possible in the laboratory investigations.

Laboratory investigation of the representative sample of the athletes is possible to compensate with the TV reproduction of the top level competitions. This fact makes possible future investigations with the main goal to determine the movement structure efficiency in certain sports.

The problem of this investigation is skiing technique in alpine skiing events, or more closely the slalom technique. Problem considered is carried out in non comfortable conditions of visual comprehension which makes it harder to directly measure certain biomechanical indicators.

Aim of the investigation is to determine set (battery) of certain kinematics situational parameters, in order to improve certain movement structures in parts of the slalom turn performed with the carving skis.

METHODS

Sample of the investigation consisted of top level skiers, winners of the final slalom race at XIX Olympics, held at Salt Lake City in 2002. (Jean -Pierre VIDAL – FRA, Sebastian AMIEZ – FRA, Alain BAXTER – GBR). This was the first race of the final men’s slalom at the Deer Valley Resort track, starting at altitude of 2488m and ending at 2274m (214m difference in altitude). 58 slalom gates were set by Jesse Perkins Hovt (USA), coach of the USA team. Total of 78 competitors started the race.

Certain parts of the track were analyzed (7 segments) with final analysis of the wide part with two wide gates (20, 21) included in this paper. Starting time of the segment was 15,76 sec., and end was at 17,60 sec. (time difference 1,84 sec.). Movement direction is left (410-438 position), right (438 – 454). Mean final time at the competition was 00:48,01 sec.

Variables of the kinematical situational space:

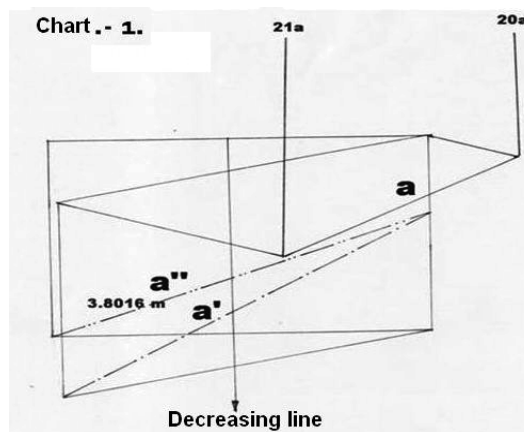
1. LENGTH (l – meter):

- 1,2,3.- Distance between representative parts of the system (skier-skis) and middle distance between front part of the bindings - ($l-TcaS$, $l-TAS$, $l-TcrS$),
4. - Length of the vertical body axis of the skier - ($l-gjBGJt$)
5. - Distance between front part of the binding left-right ski - ($l-TKMS$),

2. ANGLES - ang (degrees):

1. – Angle of vertical body axis declination from “vertical” in sagittal plane – ang-s
2. – Angle of vertical body axis declination from “vertical” in frontal plane – ang-f
- 3, 4. – Angle of the left hip (ang – sco) and right hip flexion (ang – dco)
- 5, 6. – Angle of the left knee (ang sge) and right knee flexion (ang-dge)

For the analysis of the taped material we made a special program for the graphic movement and the biomechanical analysis. Existing program *Quintic Biomechanics 9,03 v 11* was modified for the alpine skiing biomechanical analysis (at the Faculty of Physical Education in Prishtina). Upon the selection of the special phases of the experimental movements, derived material was taped again using *Aver Media system (TV Series Software Fleet – Support Windows 2000)*. To determine calibration measures we used a real length of the gate pole in slalom (1.80 m) during the movement positions.



RESULT AND DISCUSSION

To keep the calibration length in the same ratio *MGI photo SUITE* (version 4.0, Support Windows 2000) computer program was used. Using this program certain movement positions can be enlarged or made smaller so in that way the length of the calibration measure (gate pole) would be constant. The same program enabled parallel comparison of the photos in real existing space (table 1, graph 1).

Table -1. Determination of calibration measures

		3. A. BAXTER-GBR		11.S.AMIEZ-FRA		distance between gates (m)	gates nr.
	positions	P : 1	positions	P : 1	positions		
1	470-486	45.34	410-418	51.69	437-447	83.81	20a-
2	486-504	39.94	418-438	49.37	447-467	71.72	20a-21a
3	504-522	36.19	438-454	44.8	467-485	64.95	21a-
		$x=40.49$	$x=48.62$	$x=73.49$			

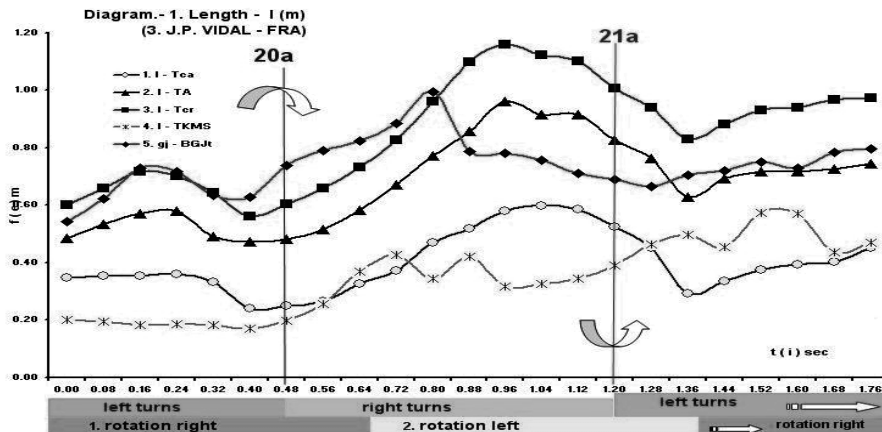
Results and discussion

In the result analysis and discussion we analyzed the results of slalom trail (segment-IIIa) taken by *Jean-Pierre VIDAL – FRA*.

1. LENGTH - l (meter), (table 2, diagram 1).

Table -2. Length - l (m)

3.Jean - Pierre VIDAL-FRA N=36	Mean	Minimum	Maximum	Variance	Std.Dev.	Stand.Error	Skewness	Kurtosis
1 I Taca	0.337	0.085	0.597	0.020	0.141	0.023	-0.054	-0.493
2 I TAS	0.577	0.210	0.963	0.044	0.210	0.035	-0.109	-0.774
3 I Tcr	0.758	0.413	1.159	0.050	0.223	0.037	0.111	-1.165
4 I gjBGjt	0.655	0.414	0.995	0.020	0.141	0.023	0.092	-0.537
5 I TTKMS	0.321	0.172	0.575	0.013	0.114	0.019	0.574	-0.517



Differences between particular representative system points are present together with the lowest maximal values of the caudal body part, *TcaS* 0.60 m, for *TAS* 0.90 m, and for *TcrS* 1.120 m.

1-2-3 distance between system representative points (TAS,TcrS,TcaS) and the middle of the front bindings distance. Maximal values are present at the end of the main phase of the turn, and decrease during the contact with the inside gate pole.

Minimal values are presented at the final turn phase.

In order to determine the oscillations during the different segments of the skier-skies system, specially in sagittal plane (upwards, downwards) during the preparation and main phase of the turn, as well as the oscillation in frontal plane (*left, right*), during the main phase of the turn (contact moment between the system and the inside gate pole in slalom) as well in the turn exit phase (final phase of the turn) we measured:

Difference between maximal and minimal results values and their basic statistical parameters in the best way show the oscillations of the system during the transfer of the system weight between skies. Largest difference is between the center mass of the caudal part *TcaS*, approximately 0.70 m while joint mass of the system *TAS* is less than 0.50 m, with the cranial mass *TcrS* at 0.60m.

More distinctly visible oscillation in relations between system mass points gives us variable:

4. – length of the vertical body axis - Value of the results show us the level of the body flexion and extension during the different phases of the turn, as the result of the skiing trail configuration. Basic statistical data table show the maximum value at 0,725 m, and minimum at 0.350 m, while mean value is at 0,489 m. During the part with the open gates, the values of the vertical body axis are similar to the distance between the cranial part of the system and mean distance between the front bindings. Minimal values are present in the moment of the contact between pole and gate pole (20 a), in which those results are larger to the maximum value of 0,995 m with the mean results ranging from 0,655 to 0,797 m.

During the skiing over the skiing trail terrain and its special parts, special role has the level of the body support area of the skier which becomes of special importance during the dynamical body balance in this paper analyzed by:

5.-Distance between the left and right ski front bindings – (1-TKMS). Although system sagittal balance position in slalom is more balanced (because of ski length), frontal balance position of the system during the skiing must be constantly controlled in that way that the skier controls the distance between the skies. Results analysis show two moments in which maximum results are achieved, first one at the end of the main phase of the turn when the outside ski goes past the inside ski, and second one when skier is closing to the gate pole, which is the result of the side skid at the outside ski and inside knee flexion. These mentioned values in this investigation for the mentioned segments are in the range from 0,365 m to 0,596m, with mean values from 0,218 m to 0,358 m.

2. ANGLE – (degrees), (table 3. diagram 2).

Table.-3. Angles - ang (degrees)										
3.Jean - Pierre VIDAL-FRA	N=23	Mean	Minimum	Maximum	Variance	Std.Dev.	Stand Error	Skewness	Kurtosis	
1	ang S	68.130	55.000	89.000	114.846	10.717	2.235	0.602	-0.976	
2	ang F	21.696	1.000	35.000	117.312	10.831	2.258	-0.553	-1.099	
3	ang dco	41.826	7.000	88.000	543.877	23.321	4.863	0.041	-0.711	
4	ang sco	61.696	3.000	140.000	2386.585	48.853	10.186	0.496	-1.514	
5	ang dge	124.043	78.000	164.000	584.043	24.167	5.039	-0.155	-0.856	
6	ang sge	107.609	40.000	173.000	2173.158	46.617	9.720	-0.221	-1.531	

1. Angle of vertical body axis declination from the “vertical” in sagittal plane – ang-s represents movement of the vertical body axis of the skier in sagittal plane and specially movement of the caudal part body mass *TcaS* of the skier-skis system. When this mass *TcaS* is located behind the cranial part of the *TcrS* system, than the body is in the bent (flexed) position of the vertical body axis, and in opposite case, when the center of mass of the *TcaS* is located in front of the center of mass of *TcrS*, the body is in the straight (extension) position of the vertical body axis of the skies. This parameter shows the vertical body axis movement oscillations in sagittal plane, and the value of the amplitude of these oscillations which are defined by the angle between the vertical and horizontal body axis. Result values show the body flexion when the angle of 90° is decreasing and body extension when the angle of 0° is increasing towards 90° .

After exiting the gate, caudal part center of mass *TcaS* is behind cranial center of mass *TcrS*, that means that from body flexion, new turn begins by vertical body axis moving toward the vertical (angle increases toward value of 90°). These angle values changes most precisely determine the time duration of the first phase of the turn most precisely (transfer of systems center of mass from inside to the outside ski).

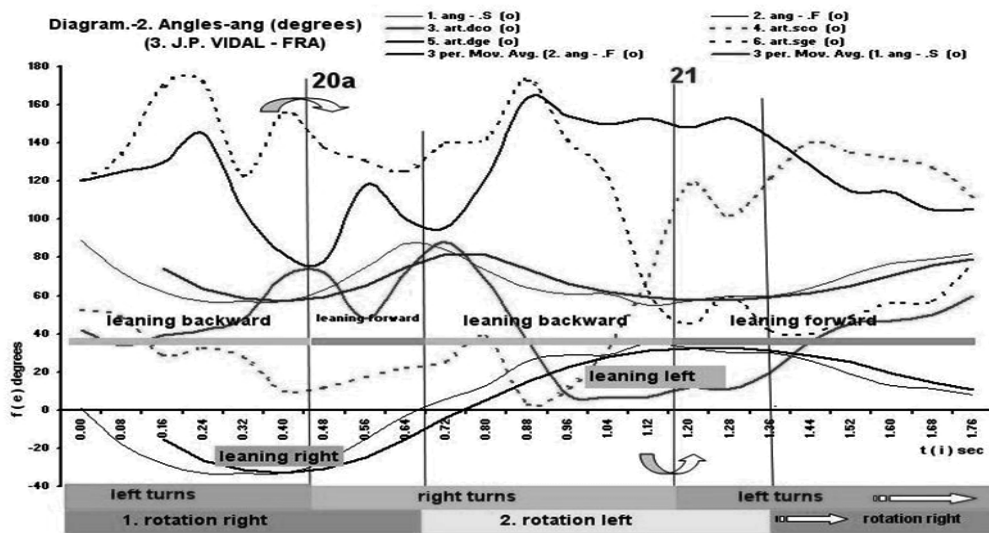
Movement continues with the extension of the body where systems caudal center of mass *TcaS* passes by the cranial center of mass *TcrS*, this means that the body extension is beginning (angle of 90° is decreasing), with angle decreasing to the moment when a pole makes contact with next gate. This can determine time duration of the main phase of the turn.

Flexion starts after the pole passes the gate, angle inclines toward the 90° value, when the caudal center of mass *TcaS* is behind the cranial part center of mass *TcrS*, and by that we can determine the time duration of the final phase of the turn.

2. Angle of vertical body axis declination from the “vertical” in frontal plane - ang-f.

This angle represents the oscillations of the vertical body axis in frontal plane, and specially the movement of the caudal center of mass *TcaS* to the right side (negative angle values) and left side (positive angle values), in relation to the vertical cranial center of mass *TcrS* of the skier-skis system. These oscillations are as the result of the dynamic body positions balance and their values depend on the movement

velocity of the systems center of mass. There is a force whose tendency is to eject the system skier-skis from the movement cycloid, which is the result of the central forces influence. This force should be decreased by harmonization of the transfer between gates, and especially at frontal plane (left – right) movements.



3.4. Angle of the left (ang - sco) and right hip (ang - dco) flexion. This is the angle between the vertical body axis of the skier and the axis of the thigh (right – left, inside-outside), and has angle values from 0 – 180°.

From the results of the systems *TcaS* caudal center of mass oscillations (left – right) is visibly clear that after exiting the last gate, vertical body axis inclines towards the center of the turn with maximum angle values from 35 do 21°. After this follows the movement towards the vertical, and angle values of 0°. These movements determine the time needed for transfer of the systems center of mass from one ski to another (first phase of the turn). Movements are continued by the body flexion towards the opposite side (next gait), until the moment when the pole passes beyond the gate, and the turn finally ends.

Hip flexion angle diagram line of the outside and inside ski, shows maximal values of the outside hip flexion from 140 – 164° at the moment when the pole passes beyond the gate. At the same moment maximum angle values of the inside hip range from 80 – 102°.

In the moment of the system mass transfer from outside to the inside ski, the inside hip flexes insignificantly, but the outside hip has already started with extension (in that way the flexion decreases and extension increases). This duration of this movement represents first phase time duration.

By continuing the main phase of the turn, extension reaches angle value of 7° . In that moment this phase ends as the outside hip flexion maintains angle values somewhat larger than minimum. At the same time flexion of the inside hip is increased significantly, especially after the pole passes beyond the gate.

5.6. Angle of flexion of the left (ang sge) and right knee (ang-dge). This angle is the angle between the axis of the thigh and the axis of the shin (right – left, inside – outside) and it has values from $0 - 180^\circ$. After the pole passes beyond the gate, inside knee flexion has maximum angle values (minimal angle value is 40°), and the outside hip reaches somewhat less flexion (maximum angle value is 87°) and is maintained longer until the main phase of the turn ends.

At the same time inside hip decreases flexion to the maximum (maximum values are from $164 - 173^\circ$). Entering the final phase of the turn, outside knee maintains its flexion, while at the same time inside knee increases flexion and reaches maximum values at the moment when the pole makes a contact with the gate. This is the result of the system mass transfer from ski to ski during the first phase of the turn, and represents transformation of the inside ski in to the outside and vice versa. Second phase of the turn (phase of ski drive) stabilize the already reached body position, when body transfers from the extended to the flexed position. This body position is maintained until the pole makes contacts with the gate and passes beyond it (final phase of the turn). This movement is characterized by skiing at the outside ski or in the most cases at the outside edge of the skis. This decreases skiing velocity which tends to maintain dynamical balance position during the slalom race.

CONCLUSION

Results of the investigation show that the value increase of one parameter influences compensatory decrease of the other parameter characteristic values. Increase of the values of the certain situational kinematical biomechanical parameters can influence the improvement of the structural slalom technique movement especially at the slalom carving skis. The determination of these parameters, in this paper, open the possibility of further investigations which will be more precise, especially in determination of the shortest slalom trajectory and better results in slalom competitions. The alpine skiing movement structure, especially slalom is defined by the vertical movement amplitudes of the center of mass in skis-skier system. Lower amplitude of the oscillation, produces longer pressure at the ski surface, which increases breaking forces and decreases skis velocity.

This is the main reason for the velocity decrease during the skiing at one ski (sliding) which is typical for the skiing at traditional skis

Today we are talking about the new model of the carving skis with a pronounced side edge arch, which enables skiing at both skis equally maintaining a constant contact with a snow.

Undeniably, widely placed skis position in skiing has dual role. Firstly, it enables faster and larger side movement of the body with the grater stability of the

dynamic balance position, and secondly it enables better distribution of the mass of the skier-skis system between the inside and outside ski and vice versa.

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SITUATIONAL BIOMECHANICAL PARAMETERS AT SLALOM CARVING SKIS IN TOP LEVEL SKIERS

Skiing is a sport performed under exceptional competition conditions, especially taking into consideration environment, skiing trail with its special characteristics. It is impossible to carry out an investigation of the alpine skiing technique in laboratory conditions. Because of that it is only possible to carry it out during a competition. In this paper we selected special parts of the trail based on the predetermined goal to determine the carving slalom skis efficiency. Besides this we determined certain markers of the slalom technique that represent biomechanical situational kinematical space parameters: length with five and angle with six variables.

Besides the investigation results, after the statistical processing, we found that the certain kinematical situational variables of slalom technique at carving skis have different mutual relations.

Key words: carving skis, skier-ski system, situational kinematical parameters, length of the vertical body axis, angle of vertical declination, flexion and extension.

„Vijesti“, 28. mart 2013.

SPORTSKA DOSTIGNUĆA: Fakultet za sport i fizičko vaspitanje i Crnogorska sportska akademija organizuju X Međunarodnu naučnu konferenciju

Da zadive svjetsku stručnu javnost

Fakultet za sport i fizičku kulturu iz Nikšića i Crnogorska sportska akademija će pod pokroviteljstvom Univerziteta Crne Gore od 4. do 7. aprila organizovati X Međunarodnu naučnu konferenciju, "Transformacioni procesi u sportu - sportska dostignuća". Uporedo u zgradi Rektorata Univerziteta Crne Gore održaće se i IX kongres Crnogorske sportske akademije (CSA). Tim povodom u Rektoratu je održana konferencija za novinare na kojoj su govorili rektor Predrag Miranović, dekan Fakulteta za sport i predjednik CSA Duško Bjelica, kao i jedan od vodećih stručnjaka u regionu iz oblasti sporta, prof. dr Pavel Opavski.

- Na konferenciji će 213 naučnih radnika, kao autori ili koautori izložiti i prezentovati 123 naučna rada. Učestvovaće naučnici iz 15 država, sa 26 univerziteta, deset sportskih akademija i 30 ustanova koje se bave sportom. Svi radovi će biti publikovani u časopisu "Sport Mont", dok će pet najboljih radova biti objavljeni i u međunarodnom časopisu na engleskom jeziku, "Montenegrin journal of sports science and medicine". Na taj način radove ćemo izložiti javnoj kritici domaće i inostrane stručne javnosti - kazao je Bjelica.

Poseban akcenat u ovogodišnjoj konferenciji "Transformacioni procesi u sportu", biće u vezi

s istraživanjem antropološkog i antropometrijskog statusa djece do trećeg razreda osnovne škole u Crnoj Gori. Istraživanje treba da obuhvati 3.000 malšana.

- Iz godine u godinu crnogorski sport pokazuje sve bolje rezultate, naročito u kolektivnom sportu, ali i pojedinačnim borbakim sportovima i atletici. U svom radu smo zahvalni na podršci resornom Ministarstvu i UCG. I nadamo se da ćemo organizaciono i tehnički biti barem jednako dobri kao prošle godine, a da li će ova konferencija nadmašiti prethodnu, sud će dati javnost nakon njenog održavanja i publikovanja radova. Na osnovu prispijelih naslova i teza, trebalo bi da ispunimo cilj. Da budemo još bolji, ali o tome je rano pričati - naglasio je Bjelica.

A iako mlad, Fakultet za sport je već uspio da se u svijetu prepozna kao regionalni centar naučnih zbiranja u domenu sporta, o čemu svjedoči pokretanje naučnih časopisa na našem i engleskom jeziku.

- Iako mlad i radi sa malim brojem zaposlenih, Fakultet za sport i fizičku kulturu postize značajne rezultate. Kolege iz sporta su perjanice u naučnom radu Univerziteta, što potvrđuje maksimum da "kad ima volje, ima i načina". Čestitam na tome Dušku Bjelici i kolegama sa tog fakulteta - istakao je Miranović.

S. ŽIVALJEVIĆ



Na konferenciji će biti prezentovana 123 naučna rada: Bjelica i Miranović

Foto: Z. BIRIĆ