KINEMATIC AND DYNAMIC ANALYSIS OF THE WIDE-RADIUS TURNS IN SNOWBIKING

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The objective of this study is to determine particular phases of the turn execution in snowbiking and the resulting time measured at the finish line. The 2D and 3D analysis should be carried out, so that the course of each kinematic and dynamic parameter could be interpreted appropriately, in order for it to be used for the purpose of mathematic modelling and by trainers, coaches and competitors. The results produced by this study, satisfied the requirements for determining particular phases of the wide-radius turn execution. In addition, statistically significant relations between the duration of the phases and the time reached at the finish were confirmed. Selected parameters were calculated and interpreted, relevant to the field of dynamics.

KEY WORDS: kinematics, dynamics, 2D and 3D analysis, movement optimization

INTRODUCTION: As is the case with most elite sports, the top performance depends on a neat, precise execution of the given movement action in extreme technical, physical and psychological conditions. In snowbiking, a sport similar to the slalom in downhill skiing, the final performance, the best time reached, depends on the optimum turn execution as the competitor passes through each gate. To assess the snowbiker´s execution in each gate and to introduce mathematic modelling to detect the optimum execution in gates, the 2D and 3D biomechanic analysis was carried out with the aid of speed cinematography (French, 1981; Cappozo, Marchetti, Tosi, 1992) and electronic video recording (Manoni et al. 1992; Kennedy, Wright and Smith 1989; Angulo, Dapena 1992; Mössner, Nachbauer, Schindelwig, 1997). In this study, there is also the possibility of using a semi-automatic computer system of data processing. The aim of the study is to detect key points and phases of particular movement actions in slalom turns, to determine this proportion in relation to the whole turn duration, and finally to interpret their influence upon the resulting finish time. Basic calculations must be obtained that are of a dynamic character, describing a snowbiker´s action when passing through a gate (round the gate pole), in order to provide the entry data for a potential mathematic model. From a thorough review of the literature sources concerning snowbiking, there is every indication that this problem has not received sufficient academic attention.
The data for this study were collected from a group of Czech competitors who had achieved recognition of top-performance in their sport. Not only do the results obtained comply with the objectives of this study, but they can be used also for formulating methods to be applied later in the training process which is focused on improving snowbiking technique of the snowbikers.

METHODS: The data were collected during the national championship of the Czech Republic in snowbiking and as a sample of probands, a team of 14 competitors was used. After assessing their performance standards, the best 6 competitors of the representation team were selected and the data collected were analysed by means of 2D speed cinematographic analysis with the frequency of 50 half-pictures/sec and exposition time 1/1000 sec (Zahalka, Sports Motorics Laboratory, Charles University in Prague). Kinematic and dynamic parameters were calculated by means of PAM method used for approximation of discrete points of individual axes´dependence on time – (Jelen, Pribramsky, 1994), and CONSPORT system for 3D analysis including software solution of spatial tasks in kinematics. 20 different points of the snowbike-snowbiker system were analysed. According to data collection and processing methods that were used, approximated data errors reached their minimum values, (Nachbauer, 1996). Basic criterion of dividing a turn in snowbiking into its particular phases, is similar to the slalom turns component in downhill skiing, (Pribramsky, Jelen, 1995). See Table 1.

RESULTS AND DISCUSSION:

Table 1 Duration of Individual Phases of the Wide-Radius Turn

S	0 - 1 [s]	1 - 2 [s]	2 – 3 [s]	3 - 4 [s]	4 - 5 [s]	0 - 5 [s]
1.	0.044	0.379	0.217	0.064	0.044	0.748
2.	0.049	0.374	0.227	0.069	0.039	0.758
3.	0.049	0.389	0.207	0.084	0.044	0.773
4.	0.059	0.384	0.202	0.079	0.069	0.793
5	0.089	0.399	0.158	0.099	0.084	0.829
6	0.094	0.404	0.141	0.108	0.089	0.836
Averr.	0.0640	0.3882	0.1920	0.0838	0.0615	0.7895
S_d	0.0200	0.0106	0.0314	0.0156	0.0202	0.0335
r_p	0.9747	0.9242	-0.9608	0.9586	0.9678	

S - final standings of the competitors
0 - 1 initiation phase – lowering the center of gravity (snowbiker+snowbike) – the angle of snowbike´s direction is not changed
1 - 2 steering phase I – the beginning of changing the angle of direction
2 - 3 steering phase II – raising the system´s center of gravity, the change of the angle of direction is finished
3 - 4 end phase – raise of the center of gravity is completed, the angle of snowbike´s direction is not chnaged
4 - 5 transition phase – the angle of the snowbike´s direction is unchanged
0 - 5 the total duration of the turn execution
Averr. - average value, S_d - standard deviation,
r_p - Pearson´s correlation coefficient , * - reliability value 0.05

Table 1 shows description of individual phases of the wide-radius slalom turn execution; the time needed for the execution was determined. The correlation coefficient of 0.05 implies that the time of each turn phase duration has a direct relation with the resulting finish time. The relation of 2 –3 phase is indirect. All identified relations are of a high statistical importance.

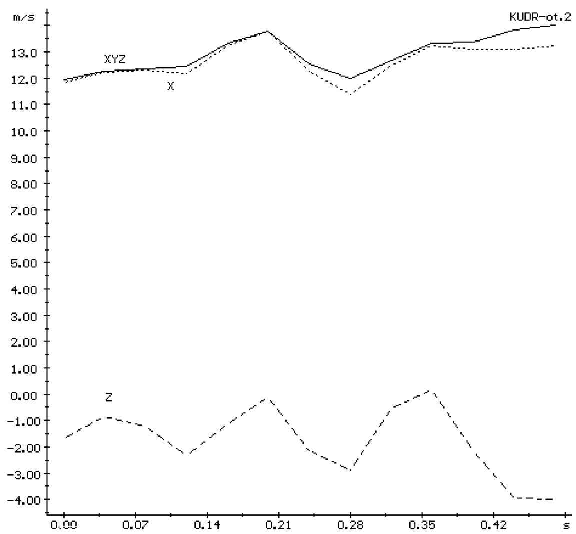
Table 2 Percentile Proportion of Each Phase in the Wide-Radius Turn

S	0 - 1 [%]	1 - 2 [%]	2 - 3 [%]	3 - 4 [%]	4 - 5 [%]	0 - 5 [%]
1.	5.9	50.7	29.0	8.5	5.9	100
2.	6.5	49.3	29.9	9.1	5.2	100
3.	6.3	50.3	26.8	10.9	5.7	100
4.	7.4	48.4	25.5	10.0	8.7	100
5.	10.7	48.1	19.1	12.0	10.1	100
6.	11.2	48.3	16.9	12.9	10.7	100
Averr.	8.58	48.88	23.00	11.05	8.50	100
R	3.27	0.81	16.51	1.44	3.62	

S - final standings of the competitors
0 - 1 initiation phase
1 - 2 steering phase I
2 - 3 steering phase II
3 - 4 end phase
4 - 5 transition phase
Averr. - average value
R - variance

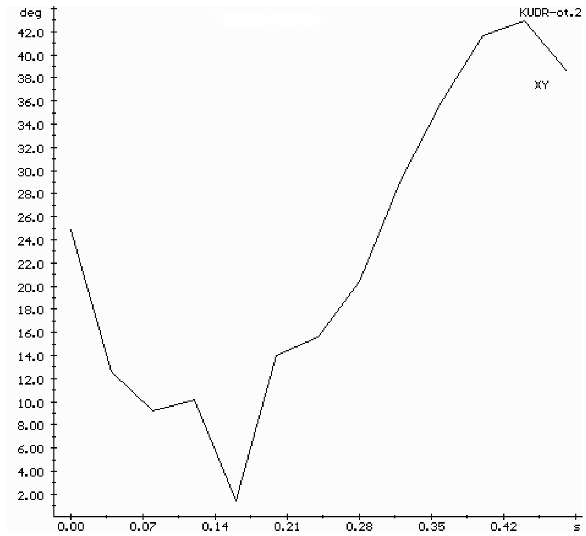
Percentile proportion of the individual turn phases when the snowbike´s direction angle within each phase is changed, and when the direction angle is not changed, is cca 72:28. When improving the turn execution to the optimum level, the most important aspect is that the competitor should be focused on active control of turning the snowbike for the longest time possible. The greater the competitors´performance, the greater is the influence/effect on the time when the snowbike is negotiating a turn, in contrast to the time when the turn is not being negotiated. On examination of the competitor’s scores, these times were in proportion of 74:26 to 80:20. This implies that coaches (trainers) should be recommended to train the execution of all turn phases, to ensure that when a snowbiker actively controls steering the skis of the snowbike and the snowbike´s direction angle is changed, the time to undertake this, is as long as possible.

Figure 1 - Real data before aproximation (3D).



— xyz – snowbike´s velocity vector in 3D
… x – axes of snowbike´s velocities in 3D
… z – axis of the rear ski tail´s speed in 3D
x – fall line   y – normal line   z - contour line

Figure 2 - Real data before aproximation (3D).



inclination of the snowbike-snowbiker system in 3D

Table 3 Selected Kinematic and Dynamic Parameters at the Moment of the Greates Inclination When Passing Through a Gate

S	v [m/s]	a [m/s^2]	r [m]	γ [deg]	ϕ [deg]	F_N [N]	F_O [N]	F_T [N]
1	13.8	14.8	17.1	44	179	1059	1202	1602
2	13.2	14.3	16.7	42	168	1099	1170	1605
3	13.6	14.6	17.2	43	172	932	1024	1385
4	12.2	12.6	18.9	33	164	932	747	1194
5	12.1	14.1	14.5	41	169	952	982	1368
6	11.2	11.3	22.4	23	172	942	537	1084

S - final standings of the competitors
v - velocity of the snowbike
a - resultant acceleration
r - turn radius
γ - inclination angle of the snowbike
ϕ - angle between longitudinal axes of the front rear ski of the snowbike
F_N - normal force exerted on the plane of the slope
F_O - centrifugal force
F_T - resultant force exerted on the snow surface

Table 3 implies that velocity of the snowbike in the examined turn phase, was reaching values up to the maximum of 14 ms^{-1}. Idividual radiuses of the executed wide-radius turn range from 14 to 22m at the moment of the greatest inclination of the snowbike-snowbiker system of the 23-44 degrees. Forces exerted on the snow surface make up a vector of the resultant force reaching values of 1000 to 1600 N. Acceleration causing excess load of the snowbiker reaches values of 1.50 ms^{-2}.
The dynamics of change further characterizes an individual turn execution, which produces many suggestions on how the techique should be improved, e.g. competitors should shorten

the duration of transition phase betwen two turns. This will enable them to utilize reaction forces effectively in changing the weight distribution and inclination of the snowbike. Consequently, the duration of controlled steering will be longer, and execution continuity will be improved with respect to necessary disadvantageous turn shortening when passing round the gate pole. Consequently, the loss of energy and brake force are decreased, which shortens the resulting time reached at the finish. It is necessary to realise that the excess load in the turns may reach the value of 2G, and in tight-radius turns the values are expected to be even higher. Therefore the competitors are recommended to undergo special training in preparation for the competition .

CONCLUSION: The study was elaborated with respect to the fact that Czech men´s and women´s representation teams are able to show top-class performances throughout the competitive season, and further improvement in technique is possible only in situations where the biomechanic principles of the snowbiking actions are clear and properly understood. Not only is introduction of a systematic division of movement phases important, but also deeper dynamic principles, in order that the trainers and competitors are provided with appropriate recommendations, for example, change in movement execution of a given turn phase. Kinematics and dynamics must be understood properly, so that some movement parameters can be used in mathematic-physic modelling. This increases the accessibility of data that are difficult to obtain, or perhaps are unmeasureable, due to the present technical conditions. This study proved to be very useful and became a pilot study for further biomechanical analysis of the top snowbiking competitions.

REFERENCES:

Angulo, R.M., Dapena, J. (1992). Comparison of film and video techniques for estimating three-dimensional coordinates within a large field. *International Journal of Sport Biomechanics,* **8**, 145-159.

Cappozzo, A., Marchetti, M., Tosi, V. (1992). *Biolocomotion: A century of research using moving pictures.* Roma, Promograph.

French, E.K. (1981). *Validity and reliability of kinematic data from two dimensional cinematography.* Unpublished doctoral dissertation, Indiana University.

Jelen, K. Přĩbramskŷ, M., (1994). Mutual comparison of Biomechanical aspects of the course of the Tight-radius and Wide-radius slalom turns-part II., *AUCK*, **2**, 83-91.

Kennedy, P.W., Wright, D.L., Smith, G.A. (1989). Comparison of film and video techniques for three-dimensional DLT repredictions. *International Journal of Sport Biomechanics,* **5**, 457 - 460.

Manoni, A., Giorgi, C., Carveli, E., & Manoni, L. (1992). Three-dimensional analysis of closed-leg circle. A comparision between two methods. In: RODANO, R., FERRIGNO, G. and SANTAMBROGIO, G. (Eds.). *Proceeding of the Xth International Society of Biomechanics in Sports.* Milano, 163-166.

MÖssner, M., Kaps, P. and Nachbauer, W. A. (1996).Method for Obtaining 3-D Data in Alpine Skiing Using Pan-and-Tilt Cameras with Zoom Lenses. *Skiing Trauma and Safety,* **10**, 155 - 164.

Nachbauer, W., Kaps, P., Nigg, B., Brunner, F., Lutz, A., Obkircher, G., & Moessner, M. (1996). A Video Technique for Obtaining 3-D Coordinates in Alpine Skiing. *Journal of applied biomechanics,* **12**, 104 - 115.

Přĩbramskŷ, M., Jelen, K. (1995). Mutual comparison of the biomechanical aspects of the course of the Tight-radius and Wide- radius slalom tarus- Part II. Kongres INTERSKI 1995, Nozawa-Onsen. *Proceedings INTERSKI*, **69***.*