SOME BIOMECHANICAL CHARACTERISTICS OF SLALOM TURN DURING RACE OF ELITE ALPINE SKIERS

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Abstract

The aim of this study is to determine the relationship between speed of passing through ski gates and variables of geometry of skiers' body during slalom race for the top alpine skiers. The parameters were recorded at the World Cup Race Snow Queen Trophy on 30 top alpine skiers participating in the second run. The Ariel Performance Analysis System was used to calculate the 3D kinematic data. We determined the distance of elite skiers' lines of skiing from the fall line and tried to establish whether the competitors with a shorter line of skiing in the gate setting achieve higher velocities and consequently better race results. The most significant correlation (r=0.95) was observed between the distance of outside ski boot and ski gate and projection of center of gravity to outside ski boot distance. Mentioned correlation is a result of skiers' effort to find an optimal position between outside ski and projection of center of gravity relative to the ski gate. Statistically significant and positive correlation (r=0.65) observed between distance of skiers' center of gravity and ski gate and distance between center of gravity and outside ski boot explains how greater distance of outside ski boot from ski gate required greater deflection of skiers' body toward center of turn in order to optimize the trajectory passing through the gate. Correlation of skiers' speed at gate and investigated variables of geometry of skiers' body was not overall statistically significant. The absence of significance between position of center of gravity, ski boots and velocity might be explainable by undemanding configuration of ski slope at filmed slalom turn and superb technical performance of investigated alpine skiers. Use of more advanced technology might be more appropriate for the investigation of subtle differences in the race performance among top alpine skiers.

Keywords: *slalom discipline, kinematic indicators, center of gravity*

Introduction

Past years in alpine skiing were marked by significant changes brought on by improvements in racing equipment, which, through impact on velocity, acceleration, forces and vibrations led to new technique development. Today, only subtle differences, measured in fractions of a second discriminate the best ranked skiers, so one of the main topics of both scientific and expert debates in alpine skiing is which technique and racing turn is better in specific conditions and might affect the ski success (Supej et al., 2005). Ski turn during specific conditions of ski racing is a complex interaction between skier on one side with his technique and tactics, and on the other side equipment and ski trajectories (Haugen et al., 2010). During slalom ski racing, the technique and the strategy of choosing the right trajectory between the gates are of utmost importance, while mistakes in technique lead to loosing speed (Federolf et al., 2013). This is the reason why alpine ski coaches focus tactics on the timing and placement of the line important for the gaining and loosing speed (Sporri et al., 2010). Many authors advocate the direct trajectory as an optimal one, but others also emphasize the importance of vertical dynamics (Moger et al., 2007). Equally important is maintaining high velocity and at the same time an optimal trajectory, which can produce high centripetal force acting on the body's center of mass (Pozzo et al., 2010). During a competition, each turn must be performed technically perfect in order for a skier not to lose speed. Many studies tried to identify the phase of ski turn during which acceleration leads to better performance (Haugen et al., 2010). For this reason, advanced video analysis or 3D kinematic analysis analyses are used (Hraski & Hraski, 2007). They enable detection of precise position of specific points and segments of the body in time and space during ski turns (Lešnik & Žvan, 2007). Interestingly, published data mainly describe the results of kinematic analyses during simulated sky polygons while there were only few reports on movement kinematics during actual ski competition (Pozzo et al., 2010). In the present study, we aimed to establish the differences in the choice of the line of skiing between 30 competitors of the Zagreb World Cup slalom. Moreover, we determined the distance of elite skiers' lines of skiing from the fall line and tried to establish whether the competitors with a shorter line of skiing in the gate setting achieve higher velocities and consequently faster sliding among the slalom gates.

Methods

The sample of participants consisted of 30 slalom racers (aged 27.12±1.15) participating in the 2nd run of 2009 Snow Queen Trophy World Cup slalom (Sljeme, Croatia). Each competitor of the 2nd slalom run was filmed with four DV cameras (Sony HDR-HC9E) operating at 50 fps with shutter speed of 1/500 sec. The space calibration was done with cube (180 cm x 180 cm x 180 cm) filmed after competition on the position of analyzed slalom turn.

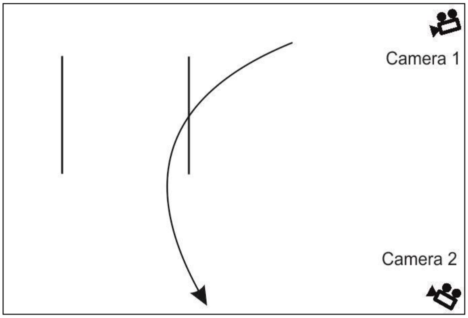

Fig. 1 Camera positions

The Ariel Performance Analysis System (APAS, Ariel Dynamics inc., USA) was used to calculate the 3D kinematic data. The kinematic variables used to describe observed slalom turn were average velocity (v) from the beginning to the end of slalom turn (Supej et al., 2003), height of center of gravity (hcg) at the moment parallel to the ski gate, center of gravity to gate distance (dcg) calculated as a horizontal distance from projection of CG to the ski gate at the moment parallel to the ski gate, inside ski boot to the gate distance (dibg) as a distance from inside ski boot to the gate, outside ski boot to the gate distance (dobg) as a distance from outside ski boot to the gate and projection of center of gravity to outside ski boot distance (dcgob) as a distance from CG projection to the outside ski boot. The Statistica ver. 7.1 (StatSoft, Inc., 2006) was used to calculate descriptive statistics and correlation.

Results and Discussion

Skiers' average speed during analyzed turn was 12.74 ms^{-1}, ranging from 12.11 ms^{-1} to 13.26 ms^{-1}. The results were similar as reported in other investigations (Lešnik & Žvan, 2007). Projection of center of gravity (CG) was 8.17 cm from pole to the center of turn, which is used as a sign of efficacy during slalom turn. Average distance between outside ski boot to the gate measured 67.71 cm. The height of center of gravity averaged to 44.03 cm (Table 1), which is compatible to results of similar studies (Schiefermuller et al., 2004).

Tab. 1 Descriptive statistics

variable	N	Mean	Min	Max	Std.Dev.
v (ms^{-1})	30	12.74	12.11	13.26	0.29
hcg (cm)	30	44.03	37.81	47.73	2.71
dcg (cm)	30	-8.17	-26.99	16.30	11.49
dibg (cm)	30	21.35	1.78	54.99	14.28
dobg (cm)	30	67.71	41.41	103.49	19.03
dcgob (cm)	30	55.62	17.16	94.51	21.69

Legend: v - average velocity; hcg - height of center of gravity; dcg - center of gravity to gate distance; dibg - inside ski boot to the gate distance; dobg - outside ski boot to the gate distance; dcgob - projection of center of gravity to outside ski boot distance

Correlation of skiers' speed at gate and investigated variables of geometry of skiers' body was not statistically significant (Table 2), mainly explainable by sample's homogeneity and subtle results variance. Important correlations are between position of center of gravity, ski boots and gates. Statistically significant and positive correlation (r=0.65) observed between distance of skiers' center of gravity and ski gate (dcg) and distance between center of gravity and outside ski boot (dcgob) explains how greater distance of outside ski boot from ski gate required greater deflection of skiers' body toward center of turn in order to optimize the trajectory passing through the gate.

Tab. 2 Correlation between analyzed variables

variable	**v**	hcg	dcg	dibg	dobg	dcgob
v	1.00	-0.23	-0.11	-0.19	-0.14	-0.09
hcg		1.00	-0.12	-0.05	0.03	0.00
dcg			1.00	0.40*	0.50*	0.65*
dibg				1.00	0.84*	0.75*
dobg					1.00	0.95*
dcgob						1.00

Legend: v - average velocity; hcg - height of center of gravity; dcg - center of gravity to gate distance; dibg - inside ski boot to the gate distance; dobg - outside ski boot to the gate distance; dcgob - projection of center of gravity to outside ski boot distance; * - significant at p=0.05

The most significant correlation (r=0.95) was observed between the distance of outside ski boot and ski gate (dobg) and projection of center of gravity to outside ski boot distance (dcgob). Mentioned correlation is a result of skiers' effort to find an optimal position between outside ski and projection of center of gravity relative to the ski gate (Tudor et al., 2009; Flores at al., 2013). From the set point of ski technique, good ski result is a consequence of best possible relationship between speed of skies and choosing a best trajectory during ski turn, with respect to terrain configuration and position of gates (Schiefermuller et al. 2005; Lešnik & Žvan, 2007). The absence of significance between position of center of gravity, ski boots and velocity might be explainable by undemanding configuration of ski slope at filmed slalom turn and superb technical performance of investigated alpine skiers.

Conclusion

In the present investigation we found no overall significant correlation between position of center of gravity, ski boots and velocity most probably explainable by undemanding configuration of ski slope at filmed slalom turn and superb technical performance of investigated alpine skiers. We did notice significant correlations between the distance of outside ski boot and ski gate and projection of center of gravity to outside ski boot distance as well as the correlation observed between distance of skiers' center of gravity and ski gate and distance between center of gravity and outside ski boot. It is possible that use of more advanced technology such as high speed video cameras, adequate application etc. might be more appropriate for the investigation of subtle differences in the race performance of top alpine ski racers.

References

Federolf, P., Reid R., Gilgien, M., Haugen, P., Smith, G. (2013). Technique analysis in alpine ski racing: what motions of a skier cause a decline in speed? In: Book of Abstracts 6th international congress on Science and skiing. (Eds. E. Műller, J. Kroll, S. Lindinger, J. Pfusterschmied, T. Stoggl), pp. 73. Salzburg: University of Salzburg.

Flores, F.G., Wimmer, M.A., Kecskemethy, A. (2013). Optimization of the center of mass trajectory in slalom skiing-a single track pilot approach. In: Book of Abstracts 6th international congress on Science and skiing. (Eds. E. Műller, J. Kroll, S. Lindinger, J. Pfusterschmied, T. Stoggl), pp. 74. Salzburg: University of Salzburg.

Haugen, P., Reid, R., Gilgien, M., Kipp. R., Smith, G. (2010). Outside ski motion characteristics in slalom. In: Book of Abstracts 5th international congress on Science and skiing. (Eds. E. Műller, S. Lindinger, T. Stoggl, J. Pfusterschmied), pp. 127. Salzburg: University of Salzburg.

Hraski Z., Hraski, M. (2007). Influence of the skiers body geometry on the duration of the giant slalom turn. In: 4th international congress on Science and skiing. (Eds Muller E, Lindinger S, Stoggl T) pp. 252-9. London: Meyer & Meyer Sport.

Lešnik, B., Žvan, M. (2007). The best slalom competitors-kinematic analysis of tracks and velocities. Kinesiology, 39(1):40-8.

Moger, T., Reid, R., Tjorhom, H., Gilgien, M., Haugen, P., Kipp, R., Smith, G. (2007). Center of mass trajectory length and performance in slalom. In: Book of Abstracts 4th international congress on Science and skiing, (Eds. E. Műller, S. Lindinger, T. Stoggl, V. Fastenbauer), pp. 154. Salzburg: University of Salzburg.

Pozzo, R., Canclini, A., Baroni, G., Canclini A. (2010). 3-D kinematic analysis of slalom in elite skiers at the Bormio World Cup ski finals in 2008. In: Book of Abstracts 5th international congress on Science and skiing. (Eds. E. Műller, S. Lindinger, T. Stoggl, J. Pfusterschmied), pp. 65. Salzburg: University of Salzburg.

Schiefermuller, C., Lindinger, S., Muller, E. (2005). The skier´s centre of gravity as a reference point in movement analyses for diferent designated systems. In: Book of Abstracts 3rd international congress on Science and skiing. (Eds. E. Műller, D. Bacharach, R. Klika, S. Lindinger, H. Schwameder), pp. 172-185. Oxford: Meyer and Meyer Sport.

Sporri, J., Kroll, J., Schiefermuller, C., Muller E. (2010). Line characteristics and performance in gigant slalom. In: Book of Abstracts 5th international congress on Science and skiing. (Eds. E. Műller, S. Lindinger, T. Stoggl, J. Pfusterschmied), pp. 57. Salzburg: University of Salzburg.

Supej, M., Kugovnik, O., Nemec, B. (2005). Kinematic determination of the beginning of a ski turn. Kinesiologia Slovenica, 9, 1, 11-17.

Supej, M., Kugovnik, O., Nemec, B. (2005). Energy principle used for estimating the quality of a racing ski turn. In: 3rd international congress on Science and skiing. (Eds Műller E, Bacharach D, Klika R, Lindinger S, Schwameder H) pp. 228-37. Oxford: Meyer & Meyer Sport.

Tudor, A., Petljak, B., Rađenović, O., Neljak, B., Ružić, L. (2009). Dinamička ravnoteža skijaša i osnovna skijaška gibanja. In: Rađenović O. et al: Alpine skiing, Croatian Association of snow sport instructors and trainers, Zagreb: Znanje, (pp. 64-73.).