OFFSET SKATING CHARACTERISTICS OF WORLD CUP LEVEL CROSS-COUNTRY SKIERS

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INTRODUCTION

The cross-country ski skating techniques have been evolving steadily over the past several years. Previous kinematic and temporal studies conducted by Smith, McNitt-Gray, & Nelson (1988); Smith & Nelson (1988); Smith, Nelson, Feldman, & Rankinen (1989); and McPherson (1991, 1993) have documented this evolution. The fastest skiers offset skated on a steeper slope with a longer cycle length, but a similar cycle rate at a given velocity. A kinematic and temporal study was conducted during the 1994 Men's World Cup Cross-Country Ski Relay competition in Thunder Bay. The purpose of the study was to develop a current kinematic and temporal profile of the World Cup level competitors based on a multiple correlation and regression analysis of selected variables.

There were two hypotheses. The first hypothesis was that a relationship existed between the dependent variable race velocity and specific independent kinematic variables. The independent kinematic variables included cycle time, cycle rate, cycle length, cycle velocity, percentage of the cycle poling, percentage of cycle skating on either leg, pole angle at pole plant, and distance between the pole tip and ankle at pole plant. The second hypothesis was that there was an order to the relative importance of these selected independent variables in predicting the dependent variable.

METHODS AND PROCEDURES

Kinematic and temporal data were collected on all 24 competitors participating in the free technique legs of the 1994 World Cup Men's Relay. A Panasonic SVHS video camera was positioned at the 1.7 kilometer mark on the five kilometer course to record a side view of the skiers offset skating on a nine degree slope. The camera was positioned approximately 15 meters, perpendicular to the trail and leveled. The field width was 10 meters. The shutter on the camera was set at 111000 to match the lighting conditions and to minimize the exposure time. The camera recorded video images at a rate of 30 frameslsecond. However, the Peak 2D Motion Analysis System software enhanced the video signal to produce a sampling rate equivalent to 60 frameslsecond.

The kinematic data were analyzed using the Peak 2D Motion Analysis System located at the Biomechanics Laboratory at Lakehead University. Key event frames were digitized for one complete cycle of the skating techniques used by each of the athletes. The key events for the offset technique included high pole plant, high foot plant, high pole release, toe-off, foot plant, toe-off, and high pole plant. These key events were chosen based on a review of the literature and for practical reasons.

The digitized image of the skiers was based on a 24 point spatial model consisting of: limb joint centers, trunk, head, and pole positions. The Peak 2D System assigned horizontal and vertical coordinates to each of these points for every frame selected for analysis. The digitized data were smoothed using a low pass, zero lag, Butterworth digital filter. The manual cut-off frequency was set at 6 Hz.

The choice of variables for kinematic analysis was based on a review of the literature and the practical limitations of the study. The variables chosen for the study included cycle time, cycle rate, cycle length, cycle velocity, uphill pole angle, and the resultant distance between the uphill pole tip and and adjacent ankle at the moment of pole plant.

Cycle time (CT) in seconds was determined from the number of video frames to complete one cycle of the skill, measured from pole plant to pole plant. Cycle length (CL) was determined from the difference between the resultant displacements of the C/M from the beginning to the end of the cycle. The skiers' C/M was calculated by the Peak 2D system from body segment parameter estimates. Cycle rate (CR) was calculated as the reciprocal of the cycle time. The average cycle velocity (CV) was calculated by multiplying the CL by the CR or dividing by the CT.

The only angular variable recorded was backward pole angle relative to vertical at the moment of uphill pole contact with the snow (UPA). All other angles could not be accurately measured without three dimensional analysis.

The resultant distance between the uphill pole tip and the adjacent ankle at the instant of pole plant was calculated from the difference of squares of the horizontal and vertical coordinates.

The temporal data were collected by counting the number of video frames between key events. The percentage of the cycle poling was calculated as the difference in frame numbers between uphill pole plant and uphill pole tip release. The percentage of the cycle skating on the uphill (PUS) and the downhill ski leg (PDS) were calculated as the difference in frame numbers between foot plant and toe off.

The Pearson product-moment correlation for pairs of variables was used to show the strength of the linear relationship between the dependent variable race velocity and selected kinematic and temporal variables. The strength of the linear relationships among the selected independent variables were also investigated. A direct multiple regression model was developed to predict race velocity. A further stepwise multiple regression analysis was performed to eliminate the least important variables for predicting race velocity.

RESULTS AND DISCUSSION

Significant relationships were found for nine variables at either the $P<.05$ or $P<.01$ 2-tailed levels (see Table 1). A significant positive relationship was found between the dependent variable CV and CL ($p<.01$, 2-tailed). The fastest skiers had the longest CL. Further significant positive relationships ($p<.05$, 2-tailed) were found between the dependent variable RV and CV, and PDS. This means that the fastest skiers skated off either leg for almost the same length of time. In addition there were other significant correlations found among the selected variables. CL increased as UPA decreased ($p<.05$, 2-tailed), and the CV increased ($p<.01$, 2-tailed). The close to vertical pole angle probably contributed to a longer force application and therefore a longer cycle length. CT decreased as the PUS and the CV increased ($p<.05$, 2-tailed). The equal time skating off either leg contributed to a shorter cycle time. The PDS increased as the PUS decreased ($p<.05$, 2-tailed).

Table 1
Correlations Between the Dependent Variable Race Velocity and Selected Independent Variables

Correlation:	RV	CL	CT	CV	PUS	PDS	UPA
RV	1.0000	0.5330**	0.0457	0.4550*	-.1681	0.5051*	-.3586
CL	0.5330**	1.0000	0.3846	0.6073**	-.2355	0.3279	-.4387*
CT	0.0457	0.3846	1.0000	-.4963*	-.4488*	0.0402	-.0635
CV	0.4550*	0.6073**	-.4963*	1.0000	0.1702	0.2428	-.3628
PUS	-.1681	-.2355	-.4488*	0.1702	1.0000	-.4787*	0.0839
PDS	-.5051*	0.3279	0.0402	0.2428	-.4787*	1.0000	-.5022*
UPA	-.3586	-.4387*	-.0635	-.3628	0.0839	-.5022*	1.0000

2-tailed significance: *$P<.05$. **$P<.01$.

RT -Race time, CL -Cycle length, CT -Cycle time, CV -Cycle velocity, PP -Percentage of cycle time poling, PUS -Percentage of cycle time on uphill ski, PDS -Percentage of cycle time on downhill ski, and UPA -Uphill pole angle at pole plant.

Selected independent variables CL and PDS were used to build a direct regression equation to predict RV. Stepwise regression showed that CL was the most important variable for predicting RV.

CONCLUSION

The results of this study have important implications for athletes who wish to offset skate at a high velocity on a steep slope. Although cycle length was the most important variable for predicting race velocity several other variables contributed to higher race velocities. Athletes should also learn to skate with a shorter cycle time, a more balanced skate off each leg, and an uphill pole angled back when planted, but close to vertical.

REFERENCES

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