SKI SKATING FORCE CHARACTERISTICS: COMPARISONS ACROSS SPEED

Gerald Smith, Bent Kvamme and Vidar Jakobsen
Norwegian University for Sport and Physical Education; email: Gerald.Smith@nih.no

INTRODUCTION

Two primary ski skating techniques, V1 and V2, have been typically thought of as uphill and flat terrain techniques, respectively. However it has become common for ski racers to push the V2 skate on steeper uphills. A recent physiological comparison of the techniques across a range of slopes found a cross-over point of relative effectiveness with similar costs on moderate uphills of about 4 to 5 degrees [1]. A 5° uphill slope was used for the measurements of the current experiment, allowing both techniques to be evaluated under similar physiological demands. Kinetic characteristics of ski skating have been measured in only a few situations [2], none involving V2 technique on uphill terrain and across a range of speeds. The objective of this experiment was therefore to determine how V1 and V2 kinetic characteristics change with skiing speed on moderate uphill terrain where racers commonly use both techniques.

METHODS

Instrumented roller skis and poles were used to measure reaction forces during V1 and V2 skating on a large treadmill with a 5° uphill slope. A small electronic device was carried which telemetered the force data to a computer for synchronous recording along with 3-D position data. Markers on skis and poles were tracked using a Qualisys ProReflex system at 240 Hz. Using ski and pole positioning to orient the resultant reaction forces in the lab coordinate system, force components were calculated. From the force data, cycle characteristics, impulse, peak and average force (over a cycle) were determined.

Eight elite-level male skiers participated in two data collection sessions which were randomly assigned to a technique (V1 or V2 skating). After a warmup, ski speed was systematically increased from moderate to faster than race-pace relative to each skier's capability. Three speeds within this range were analyzed. At each speed, 15 seconds of force and position data were recorded from which six cycles were analyzed. Mean values across the six cycles were used to represent a skier's characteristics at that speed.

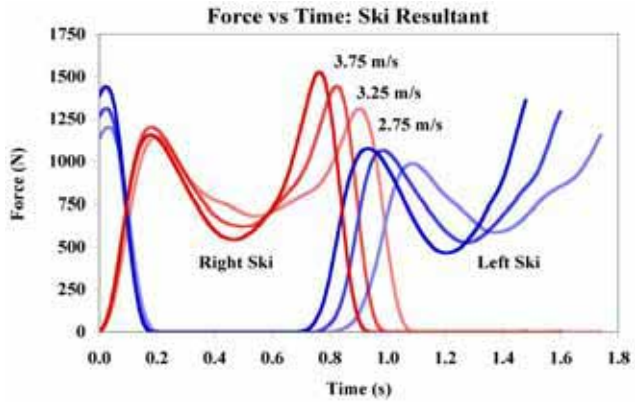

Figure 1: Resultant Ski Force vs. Time. These graphs from one skier illustrate the typical pattern of decreasing phase time and increasing peak forces as speed increases.

RESULTS AND DISCUSSION

Cycle characteristics changed systematically for both skating techniques with both cycle length and frequency increasing with speed ($P < 0.001$). Thus, control of skating speed on uphill terrain follows a different pattern than on the flat where frequency dominates [3]. Ski angle with respect to forward direction affects the proportion of reaction force which is propulsive. While ski angles were different for V1 and V2 techniques (about 19° vs. 15°) these changed little with speed. Peak forces (Figure 1) of both skis and poles increased with speed ($P < 0.02$) while average forces over a cycle were nearly constant. Average propulsive force summed across skis and poles did not change with speed (Figure 2). The proportion of propulsive force from poling was about 50-55% for V1 and 70-75% for V2 skating with each decreasing slightly with increased speed ($P < 0.03$).

CONCLUSIONS

Treadmill ski skating forces change systematically in magnitude and timing as speed increases. However propulsive force component remains relatively constant with increasing speed as the resistive forces opposing motion (gravity and ski drag) do not change with speed.

REFERENCES

1. Kvamme B, et al. *Eur J Appl Phys*, in press.
2. Millet GY, et al. *MSSE* **30**, 1645-1653, 1998.
3. Nilsson J, et al. *Sports Biomech* **3**, 85-107, 2004.

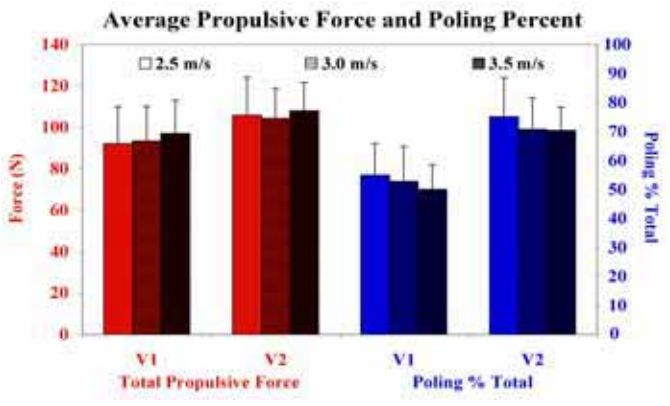

Figure 2: Total propulsive force was nearly constant across speeds however the proportion between ski and pole propulsion was different for the two techniques (V1 and V2 Poling % Total).