



# SKI SKATING BIOMECHANICS: INDIVIDUALIZED ASSESSMENT AND GENERAL PRINCIPLES

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## INTRODUCTION

Optimization of technique to improve performance is a complex, inter-disciplinary process to which sport scientists can contribute data and understanding. In cross-country skiing, it has been observed that peak aerobic capacity using skating is often somewhat lower than for classical technique (Broks & Holm, 2000). This suggests that skating technique for some skiers may not be optimal and may limit attainment of their true maximal aerobic capacity in skating. This ongoing project has aimed to understand individual skating characteristics and sought general principles for optimizing skating. In some cases, suggestions for technique modification have been implemented with specific skiers who were trying to improve technique.

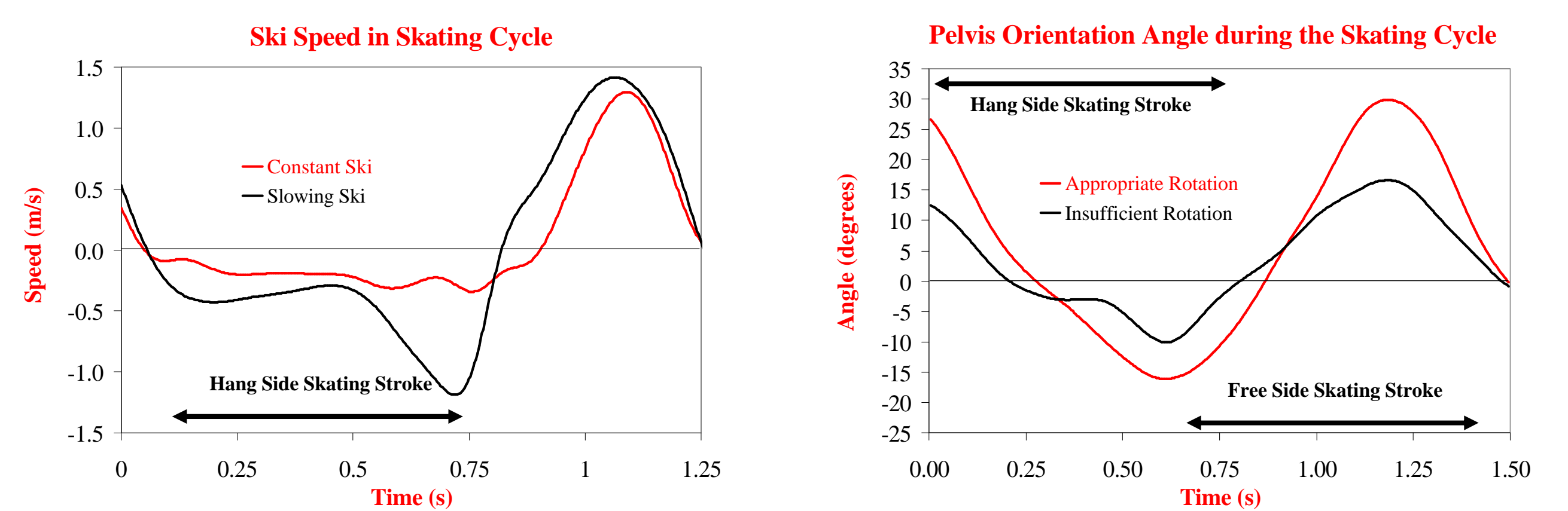
## METHODS

Seven national level skiers from cross-country and biathlon disciplines have been analyzed over about two years. Kinematic and physiological measures were obtained during uphill roller skiing on a large treadmill at 3 m/s and slopes of 5, 6 and 7 degrees with 6 minute periods for each slope. These required submaximal metabolic demands for the high level skiers of the study. Subjects have been repeatedly measured with about 6 months between sessions. Skier kinematics were measured in 3-D using a Qualisys ProReflex system with full body reflective marking of segments, roller skis and poles. Heart rate and oxygen uptake were measured throughout each session while blood lactate was measured at the beginning and end of a session. Observations have been very individualistic, hence generalizing to all skiers is probably inappropriate, however some principles have emerged from the study based on comparisons of skiers with good performance results to those with lower results.

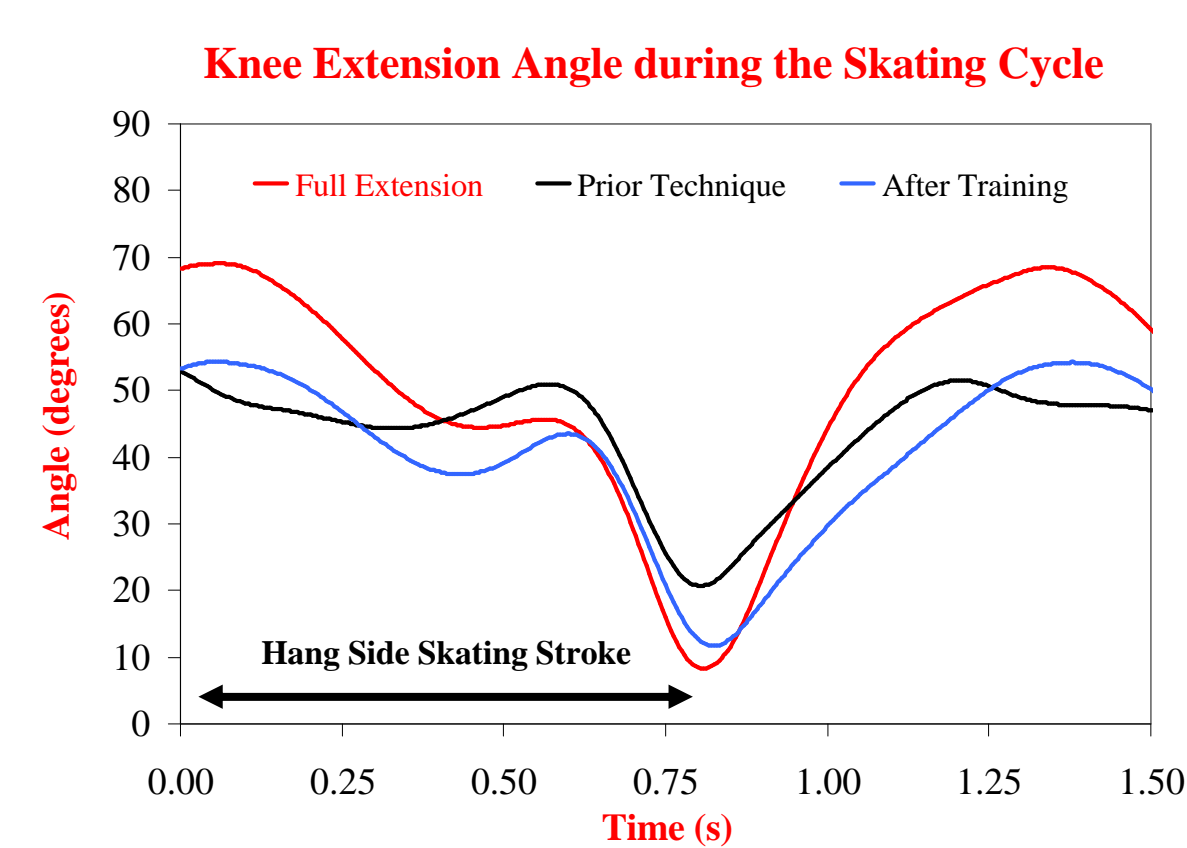


## RESULTS

Differences in technique were observed across subjects. Major distinguishing characteristics of better performing skiers were an ability to maintain ski speed throughout the skating stroke and to orient the pelvis to the direction of the ski glide on each side.



**Figures 1 and 2.** Ski speed during the skating stroke should be as constant as possible. Speed zero is treadmill speed. Pelvis orientation should be in the direction of the ski glide at the beginning of each skating stroke. On each graph the red curve reflects good uphill skating technique while the black curve includes some inappropriate characteristics for optimal skating.



**Figure 3.** Knee extension angle during the skating stroke should begin from a relatively flexed position and extend to a nearly straight leg at the end of the stroke (red curve). Knee extension characteristics can be trained to optimize technique. The skier illustrated (black and blue curves) reduced lactate levels under constant conditions with fuller knee extension.

## DISCUSSION

Ski speed during the skating stroke results from the forces acting upon it which come from skier applied reaction forces and drag forces. Body positioning directly impacts the reaction forces. Based on comparison observations and general mechanics, we believe optimal uphill skating technique will involve an immediate beginning of leg extension as the ski touches the surface. Further, the ski set down and continued motion should remain near the skier's center of mass without a large forward step from one ski to the other. While the skating forces generate substantial side to side motion, poling forces are probably best oriented to follow center of mass motion. This requires trunk rotation involving both pelvis and shoulders in parallel.

During the course of this project, technique optimization has occurred for several skiers who had performance improvements which we associate with mechanical changes independent of fitness level (figure 3). Their repeat sessions on the treadmill involved a general reduction of metabolic cost and lactate level under constant conditions.