A COMPARISON OF HIP AND KNEE JOINT KINEMATICS BETWEEN TWO ALPINE SKI ERGOMETERS

M. K. Miller, J. Porcari, D. Audet, C. Csontos

University of Wisconsin - La Crosse
La Crosse, Wisconsin, USA

INTRODUCTION

Approximately 10 million people in the United States ski, with each individual skiing an average of four times per year (Taunton et al., 1988). Although downhill skiing is a physically demanding sport, the majority of its participants can be categorized as sedentary in terms of work and exercise habits. Furthermore, participation in downhill skiing is limited to a few months each year thus making it difficult to stay in good skiing form year round.

Johnson et al. (1980) reported that there are approximately 500,000 ski injuries per year in the United States. Lack of fitness appears to be an important predisposing factor to many ski injuries since studies consistently show higher injury rates at the end of the ski day. Knee injuries are most common, accounting for 20% of all injuries in all age groups (Taunton et al., 1988).

A few companies, namely Fitness Edge and NordicTrack, have manufactured alpine ski ergometers in an attempt to allow skiers to train year round, thus keeping skiing mechanics consistent and fitness levels high. Porcari et al., (1993) investigated the physiological responses of 27 experienced skiers (14 females, 13 males) as they "skied" on two different ski ergometers. They concluded that when exercising at comparable horizontal displacements and cadences, oxygen consumption and heart rate were higher when skiing on the NordicSport in comparison to the Skiers Edge. Since both machines are fairly similar in design, it was the intent of this study to investigate the hip and knee joint kinematics as subjects skied on each machine at two speeds.

METHODOLOGY

Eleven male recreational skiers (age 21.8 ± 2.6 yrs; stature 1.76 ± 0.05 m; mass 75.5 ± 9.4 kg) participated in the study. Subjects were provided a minimum of three practice sessions to accommodate to the ski ergometers. Subjects were instructed to match the pace of an electronic metronome as they practiced.

Reflective markers were placed on five anatomical landmarks (lateral head of the fifth metatarsal, lateral malleolus, lateral femoral condyle, greater trochanter, and greater tubercle of the humerus) to derive a four segment model. Kinematic data were obtained using a Panasonic high speed shuttered video camera with a 1/1000 shutter factor operating at 30 Hz. The camera was positioned 9.7 meters from the plane of motion and aligned to obtain left side sagittal views of the subjects. During the randomized test, subjects "skied" with poles for two minutes on each machine at fast (102 turns/minute) and slow (92 turns/minute) speeds. Each subject was videotaped during the last thirty seconds of each two-minute exercise bout. Three consecutive turns were digitized from video tape and processed using the Ariel Performance Analysis System (APAS). After the data were smoothed using a cubic spline filter, relative knee and hip angles were computed. The mean, standard deviation, maximum, minimum, and range were calculated for each trial. Paired t-tests were performed on each kinematic parameter between the conditions. Significance was determined at the $p<0.05$ level.

RESULTS AND DISCUSSION

Summary data for the knee angles across the four conditions are provided in Table 1.

Table 1. Summary statistics of knee angle for each condition.

	NordicSport Fast	NordicSport Slow	Skiers Edge Fast	Skiers Edge Slow
Mean angle	139.3	141.0	143.7	143.9
Standard Deviation	5.2	7.0	7.8	6.8
Maximum angle	145.8 *	152.4	154.3	153.8
Minimum angle	128.9	129.1	125.7	152.6
Range	16.9	23.3	28.6	21.2

* Significantly different than NordicSport Slow and Skiers Edge Fast ($p<0.05$)

There were significant differences in the maximum knee angle between the fast and slow speeds on the NordicSport. As speed increased, knee flexion increased. Knee flexion was significantly greater when skiing on the NordicSport in comparison to the Skiers Edge when exercising at the fast speed. The increased flexion may have been in response to balance requirements, thus by lowering the center of mass, the subject may have achieved better balance at the faster speed. Similar balance considerations were not evident between machines at the slow speed or on the Skiers Edge between the two speeds as there were no significant differences in knee position.

Summary data for the hip angles across the four conditions are provided in Table 2. There were also significant differences in the maximum hip angle between the two machines at the fast speed. There were no significant differences in maximum hip angle between machines at the slow speed or between the slow and fast speed on each machine. The increase in hip flexion on the NordicSport may again represent balance requirements necessary to maintain a fast speed.

Table 2. Summary statistics of hip angle for each condition.

	NordicSport Fast	NordicSport Slow	Skiers Edge Fast	Skiers Edge Slow
Mean angle	136.7	139.4	141.9	143.5
Std.Dev.	8.9	9.9	9.8	11.4
Maximum angle	148.9 *	153.7	158.0	158.9
Minimum angle	124.1	126.5	127.5	122.8
Range	24.8	27.2	30.5	36.1

* Significantly different than Skiers Edge Fast ($p<0.05$)

CONCLUSIONS

Downhill skiing is one of the few sports that can be practiced on a limited basis due to seasonal constraints. Most skiers strive to ski as much of each day as their physical condition will allow, however, as fatigue sets in, the incidence of injury is likely to increase. Sport specific aerobic workout machines for downhill skiers have been developed to aide skiers in maintaining their fitness levels during the off season. Subjects skiing on the NordicSport ski ergometer achieved a greater degree of flexion at the hip and knee during the fast speed. There were no significant differences in hip and knee angles between machines at the slow speed. Skiing on the Skiers Edge ski ergometer did not produce any significant changes in hip and knee flexion from slow to fast trials. The increase in flexion at the hip and knee joints may have been a response to balance requirements necessary to maintain a fast speed on the NordicSport. How closely the two ski ergometers simulate actual downhill skiing kinematics is unknown and warrants further investigation.

REFERENCES

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