INTERNAL PROPERTIES OF CROSS-COUNTRY SKI EQUIPMENT

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Since Bill Koch won the silver medal in the 1976 Olympic Games, Nordic skiing has exploded in popularity in the United States both as a recreational and as a competitive sport. As other skiers have pursued the goal of world championships, coaches and researchers have joined ranks in an effort to improve American cross-country skiing. Because of the lack of information about the inertial properties of ski equipment, most biomechanical analysis of both Nordic and Alpine skiing has been limited to kinematics. Shonle and Nordick (1972) did a limited analysis of three brands of slalom skis and one type of downhill ski in an effort to provide inertial ski information which could be applied to the study of those events. For slalom skis the moment of inertia was .80 kg-m^2 and the value of 1.154 kg-m^2 was obtained for the downhil ski. The purpose of this study was to determine, by means of the suspension method, the inertial properties of the boots, poles and skis used by cross-country skiers in training and in competition.

Procedures The ski equipment analyzed in this study represented six types of skis (without bindings), three types of poles, and three types of boots typically used by junior and senior men in national level competition at that time. A variety of lengths and sizes were tested for each piece of equipment. In the case of the roller ski, often used for training when snow is lacking, only one brand was tested.

A specially designed device was constructed to provide a razor-edge point of oscillation for each piece of equipment. Skis were suspended by the tail, poles were suspended by the tip and boots were clamped at the toe. The roller ski was suspended from a rod through the center of the front wheel. In each case the suspension of a meter stick was used to obtain a correction for the device itself which was subtracted from the values obtained by oscillation of the equipment and device from a position of 5 degrees from the vertical.

The period of oscillation was measured using a Beckman Universal Counter/Timer 7360C which was triggered by a photoelectric cell (Figure 1.). The mean of five oscillations averaged for five trials was recorded as the oscillation period for each piece of equipment. A Tektronix Type 564B Storage Oscilloscope was employed to verify the counter value. The weight of each object was determined by use of an Ohaus 15000 digital scale. The forumula used for determining the moment of inertia about the center of gravity was as follows:

$$I_{CG} = \frac{GLMT^2}{4\pi^2} - L^2M$$

WHERE:

I_{CG} = moment of inertia at center of gravity in km-m^2

L = distance from center of gravity to suspension point

G = gravity

M = mass of object in kg.

T = period of oscillation

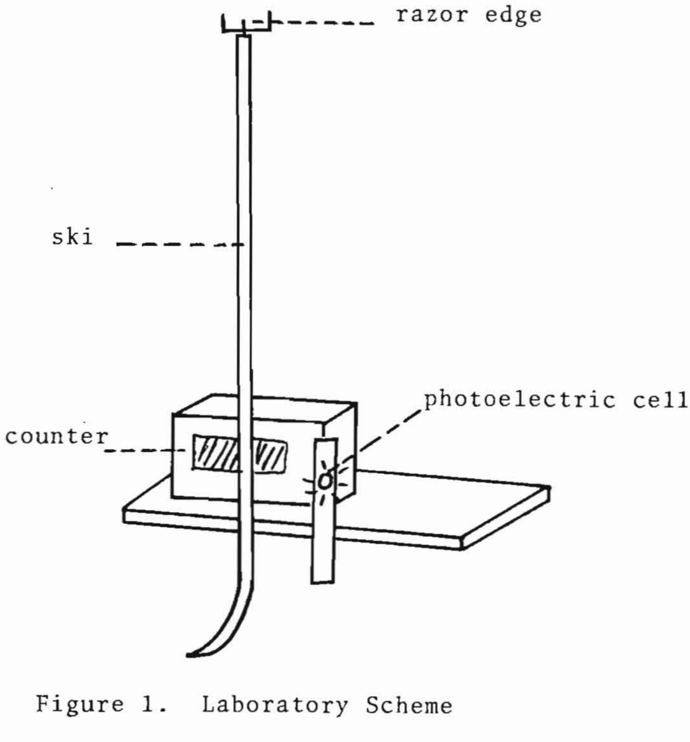

Figure 1. Laboratory Scheme

Discussion of Results Means and standard deviations for skis, boots and poles are presented in Table 1. Although the trend is moving toward reduced weight in cross-country ski equipment used for racing, it would appear that variation in the skis is very small. Competitive skiers using these averages would be carrying an additional 2.44 kilograms in weight as a result of skis, poles and boots. For a breakdown of each piece of equipment see Tables 2,3 and 4.

Table 1. Mean Inertial Values for Ski Equipment

EQUIPMENT	WEIGHT (gm.)		DISTANCE To C o G(m.)		I_{CG}(kg-m^2)	
SKI	696.11	± 50.0	.982	± .021	.1794	± .017
ROLLER SKI	1800.00	N/A	.480	N/A	.2209	N/A
POLE	195.9	± 11.7	.808	± .032	.0509	± .006
BOOT	329.6	± 30.1	.194	± .008	.0016	± .0003

Table 2. Inertial Values of Poles

BRAND/MODEL	LENGTH (cm.)	WEIGHT (gm.)	DISTANCE TO C o G (m.)	I_{CG} (kg-m^2)
KAHRU (Carbon Fiber)	150	191.4	.848	.0585
KAHRU (Carbon Fiber)	145	170.4	.795	.0441
EXEL (Final)	145	198.1	.773	.0509
EXEL (Winner)	150	201.6	.823	.0521
EXEL (Winner)	140	195.4	.763	.0424
SCOTT (Art)	145	197.7	.798	.0465
SCOTT (Art)	150	202.1	.818	.0537
SCOTT (Art)	155	210.6	.848	.0578

Table 3. Inertial Values of Skis

BRAND/MODEL	LENGTH (cm.)	WEIGHT (gm.)	DISTANCE TO C o G (m.)	I_{CG}(kg-m^2)
KNEISEL (Super Star WM)	215	703.0	.988	.1858
ROSIGNOL (Equipe)	215	702.0	1.020	.2087
PELTONEN (Finn Super)	215	747.4	1.000	.1934
FISCHER (SC)	210	648.5	.985	.1630
EPOKE (6000)	210	779.6	.988	.1980
EPOKE (500)	210	603.9	.985	.1561
KAHRU (Champion)	210	716.0	.985	.1783
KAHRU (Kevlar Racer)	210	665.2	.968	.1650
KAHRU (Champion)	205	679.0	.953	.1674
EPOKE (600)	205	716.5	.953	.1774
ROLLER SKI				
EDSBYN	N/A	1800.0	.480	.2209

Table 4. Inertial Values of Ski Boots

BRAND/MODEL	SIZE	WEIGHT (gm.)	DISTANCE TO C o G (m.)	I_{CG} (kg-m^2)
ADIDAS (SUOMI)	9	332.6	.190	.0018
KAHRU	9	309.2	.185	.0013
SUVEREN	9	291.1	.190	.0012
ADIDAS (SUOMI)	10	348.3	.200	.0018
ADIDAS (SUOMI)	11	366.6	.205	.0019

In summary, it is clear that research in cross-country skiing should not ignore the weight of approximately 2.44 kilograms of equipment used by the skier if the kinetic energy output of the various techniques is considered. When the exact type of ski, pole or boot is not known, researchers can use the mean values of Table 1. as an approximation of the weight and moment of inertia when conducting kinetic energy studies; however, it would be best to use the inertial properties of specific equipment used by the skier when possible. Although figures obtained in this study represent equipment used primarily by men, some of this equipment is also used by women and would be suited for use in studies of the kinetic energy of women cross-country skiers.

Reference

Shonle, J.I., Nordick, D.L., The physica of ski turns. *The Physics Teacher* 10:9:491-497, 1972.