CHANGES IN TECHNIQUE-SPECIFIC VO_2MAX AND COMPETITIVE PERFORMANCE IN COLLEGIATE CROSS-COUNTRY SKIERS

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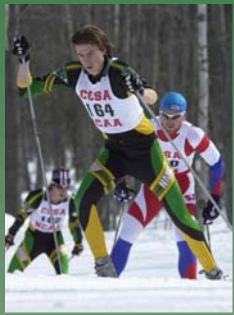
INTRODUCTION

Competitive cross-country skiers are well known for very high VO_2max values. Through the 1990's, total body VO_2max in world-class skiers ranged as high as 90-95 $ml \cdot kg^{-1} \cdot min^{-1}$ for men and 73-79 $ml \cdot kg^{-1} \cdot min^{-1}$ for women (Rusko, 2003).

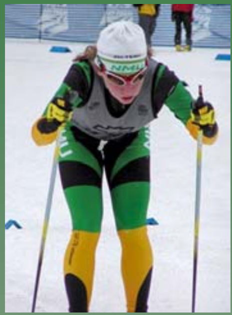
Mahood, et al. (2001) suggested the use of ski-specific testing to evaluate relationships between physiological measurements and performance in skiing. This group found a strong relationship between upper-body VO_2max and a race performance based ranking and a 10-km time trial. Rusko (2003) has reported double-poling VO_2max values between 88-93% of skating technique VO_2max.

Although there is a historical trend to link increases in total-body and upper-body VO_2max values with faster racing, the available research is limited. It is not clear whether a given physiological change will be reflected in a significant change in race performance.



V1 Technique On Snow

Lab Roller-Ski Test



DP Technique On Snow

METHODS

Ten (5 male, 5 female) competitive cross-country skiers volunteered and signed informed consent to participate as subjects in the study. The subjects were members of the same collegiate ski team and followed the team training plan and racing program throughout the 24 week duration of the study. The study was approved by the NMU Human Subjects Research Review Committee.

Laboratory testing occurred during two periods: at the end of the pre-season training and just prior to the beginning of the competitive racing season (T1), and at the end of the competitive season (T2).

Each laboratory testing period involved two maximum graded exercise tests conducted a minimum of 48 hours apart. The maximum exercise tests involved roller skiing with ski poles on a motorized treadmill (FitNex) with a belt dimension of 2.44 m (width) by 3.05 m (length). Subjects employed V1/V2 (SK) technique for one test and double-poling (DP) technique for the other test. All subjects had prior experience roller-skiing on the treadmill. Prior to the start of all exercise tests, the subject completed an accommodation period that involved roller-skiing on the treadmill at 2% grade and 2.24 $m \cdot sec^{-1}$ for a 5-min period. For the SK protocol, subjects began the test at 2% grade and a speed of 3.36 $m \cdot sec^{-1}$ for males or 2.91 $m \cdot sec^{-1}$ for females. Speed was held constant throughout the protocol and grade was increased by 1% per 60 sec. For the DP protocol, all subjects began at 7% grade and 2.46 $m \cdot sec^{-1}$. Grade was held constant and speed was increased by 0.13 $m \cdot sec^{-1}$ every 60 sec for males and every 120 sec for females. All exercise tests were carried to a point where the subject could no longer maintain the imposed work demand of the treadmill. Each subject was connected via a waist/hip harness to a safety rope during all exercise testing. The safety rope was controlled by a technician to prevent falls as the subject reached and/or exceeded a maximum work level. All subjects used Marwe 600 Skate roller-skis for the SK test and Marwe 610 Classic roller-skis for the DP test. Subjects used their personal sets of outdoor roller-ski poles sized per technique.

Expired air was analyzed continuously via an automated breath-by-breath expired air analysis system (SensorMedics VMax29c) and heart rate (HR) was recorded at 5-sec intervals (Polar Vantage XL). The expired air analysis system was calibrated prior to each subject's test via a 3-point known gas concentration method and the mass flow sensor was calibrated via a certified 3-liter syringe. Breath-by-breath data were averaged over 30-second intervals. Maximum VO_2 and maximum HR were identified as the highest 30-second interval average observed over the last 120 seconds of the skier's test.

Ratings of competitive performance were determined from the individual subjects' performances in five early-season (December) races and five late-season (March) races. United States Ski Association (USSA) Points were determined for each skier for each race according to the formula:

$$\text{Points} = [(F - T_x) / T_o] - F$$

F = F-value of 800 for mass start races and 600 for interval start races
Tx = Time of the subject in seconds
To = Time of the race winner in seconds

A final points value (PTS) was calculated for each subject by averaging the subject's best three race Points for early-season (PTS1) and late-season (PTS2).

RESULTS

Results are presented in Table 1. SK VO_2max did not significantly change from T1 to T2 for the whole subject group or by gender subgroup. Female subjects experienced a significant increase in DP VO_2max from T1 to T2 while DP VO_2max decreased in males.

Both females and males had improvements in PTS from early to late season, however only the change for females was statistically significant (mean change of -11.8±8.3 Points).

Relative T1 DP VO_2max values were 82.2±9.7% and 91.1±3.7% of SK VO_2max for females and males respectively. At T2, DP VO_2max was 84.7±6.9% and 86.2±3.8% for females and males respectively. None of the differences in Relative DP VO_2max (% SK VO_2max) were significant.

SK VO_2max and DP VO_2max were not correlated with PTS at either T1 or T2 (r values ranged between -0.31 and -0.07). It is interesting to note that the highest correlations found for any variable versus PTS2 were for T1 SK HRmax (194±11 $b \cdot min^{-1}$) with r = 0.86 and T1 DP HRmax (187±12 $b \cdot min^{-1}$) with r = 0.85.

Table 1. Means (± std. dev.) for selected variables at T1 and T2

	T1			T2		
	SK VO_2 $ml \cdot kg^{-1} \cdot min^{-1}$	DP VO_2 $ml \cdot kg^{-1} \cdot min^{-1}$	PTS1	SK VO_2 $ml \cdot kg^{-1} \cdot min^{-1}$	DP VO_2 $ml \cdot kg^{-1} \cdot min^{-1}$	PTS2
All Subj.	65.1±7.5	56.6±9.9	123.3±18.8	65.6±4.9	56.0±4.2	111.9±21.1*
Females (n=5)	59.8±3.0	49.0±4.8	125.5±20.2	63.0±3.7	53.3±3.1*	109.7±12.4*
Males (n=5)	70.3±7.0	64.1±7.4	121.0±19.4	68.2±4.8	58.7±3.5*	114.1±28.8

* Indicates significantly different from T1 ($p<0.05$).

CONCLUSIONS

Training induced improvement in double-poling VO_2max ($ml \cdot kg^{-1} min^{-1}$) may contribute to increased performance at the end of the competitive season. Although the subject sample size in this study is small, the high correlations between maximum heart rate and the performance score invite exploration of this phenomenon.

REFERENCES

Mahood, N.V. et al. Physiological determinants of cross-country ski racing performance. *Med. Sci. Sports Exerc*., 33(8):1379-1384, 2001.

Rusko, H. Handbook of Sports Medicine and Science - Cross Country Skiing. Blackwell Science, 2003.