



Roller-Ski Aerobic High-Intensity Interval Training Improves the VO₂max and Anaerobic Power in Cross-Country Skiers

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ABSTRACT: The purpose of this study was to investigate the 8-week of roller-ski aerobic high-intensity interval training on aerobic and anaerobic power in cross-country skiers. 10 male (age, 18.3±2.1 years; height, 171.3±4.12 cm; weight, 61.4±6.28 kg) and 8 female (age, 16.1±0.3 years; height, 158.3±6.47 cm; weight, 49.3±0.7 kg) junior cross-country skiers completed the study. All skiers performed 2x2-km all-out uphill intervals with roller-skis, 3 times a week, in addition to their traditional training program. Measurements included maximal oxygen consumption (VO_{2max}), anaerobic power, and also for 2-km time-trial performance. All values were listed as pre-to post-test mean (±SD), significant level, and percentage changes (%). Pre-to post-testing changes in VO_{2max}, anaerobic power, and also 2-km time-trial performance were significantly higher during all post-test trials in all groups (p<0.005). As a result, we suggest that the skiers should integrate the roller-ski aerobic high-intensity interval uphill models in their training programs for improving performance.

KEY WORDS Endurance Performance, Uphill Training, Time-Trial Performance

INTRODUCTION

Cross-country skiing is a physiologically demanding endurance sport [1, 2, 3, 4], and includes skiing and training on the flat, uphill, and downhill. Components regarding performance in cross-country skiing are complex. Studies have indicated that elite cross-country skiers have highest values in endurance athletes [5, 6]. The relevance of VO_{2max}, time to exhaustion, lactate thresholds, upper body power output, and peak upper body oxygen consumption for cross-country skiers has been also confirmed by some studies showing a relationship between these test variables and competitive performance capacity of cross-country skiing [7, 8].

Traditional cross-country skiers have shown some of the highest VO_{2max} in

endurance athletes [2, 9]. In the last decade, starting with introduction of the skating technique, a number of changes have been introduced into cross-country (XC) skiing. New competitions formats, such as pursuit, mass-start and sprint races have increased. In parallel all these change, physiological and anthropometrical characteristics of skiers have considerably changed and skiing performance is also dependent on skiers' anaerobic capacity of upper and lower body [2, 10]. The absolute values of VO_{2max} exhibited by elite sprint and distance skiers are similar, but the sprint skiers also have higher anaerobic capacity [2]. For these reasons, skiing training programmes commonly include aerobic and anaerobic conditioning.

The effects of aerobic and anaerobic training in XC skiing has been recently

confirmed by Mahood et al. (2001) [10], who tested a group of collegiate skiers during preseason. Lactate threshold, VO₂max were determined with three field-testing sessions on roller skis and peak upper-body oxygen uptake was determined with a 1-km double-pole time trial was performed. In summary, they showed that the both upper-body aerobic and anaerobic power were important for cross-country skiing performance. Additionally, previous studies on cross-country skiing have investigated a potential association between both aerobic and anaerobic power and cross-country skiing performance [1, 11, 12, 13, 8]. Österas et al. (2002) [14], investigated association between upper body endurance and the achieved 10-min ski ergometer in 19 cross-country skiers. Sandbakk et al. (2013) [15], demonstrated that the effectiveness of aerobic high-intensity training on endurance performance and oxygen uptake in national level junior cross-country skiers. Recently, high intensity interval training (HIIT) has become popular due to provide rapid aerobic improvements in endurance athletes [16, 17]. Also it is well known that these types of aerobic trainings improve performance in well-trained endurance athletes [15, 16]. Traditionally, endurance athletes have trained according to approach of high volumes at low intensity and moderate volume at high intensity. Cross-country skiers normally use this training approach (called polarized model) in their training [15, 12]. Also the off-season is a vital training period to improve skiers' performance. Skiers commonly use running and roller-ski trainings in these months [18]. Therefore, the purpose of this study was to evaluate the effects of 8-week program of roller-ski high-intensity interval training on aerobic/anaerobic power in cross-country skiers.

METHODS

The intervention 8-week training period conducted after the winter season from the beginning of April to the end of May during the roller-ski competition and

also preparation of the new winter season. All skiers performed a 2x2-km all-out uphill intervals with roller-skis (144 m height differences track), 3 times a week in addition to their traditional training program. The intervention training as follows;

-Aerobic high-intensity training, performed 2 sets as long duration (10-15 minutes), at 85-92% of HR_{max} with total work periods durations of 40-45 minutes.

The Population and Sample of the Study

The 18 cross-country skiers who participated in the study included 10 male (age, 18.3±2.1 years; height, 171.3±4.12 cm; weight, 61.4±6.28 kg) and 8 female (age, 16.1±0.3 years; height, 158.3±6.47 cm; weight, 49.3±0.7 kg) junior cross-country skiers. The study was approved by the ethics committee of the University of Gazi Medical Faculty, and all participants were gave their written, informed consent to before participate.

Data Collection Tool

VO₂max was measured by maximum stepwise exercise protocol using the Cosmed Quark CPET System (Rome, Italy), in a breath-by-breath mode while running on a treadmill (HP COSMOS, Germany). Consuming of oxygen (VO₂) and hearth rate (HR) were recorded every 2 minutes. Before the test a 15-min warm-up was performed at 60% maximal HR (HR max) on treadmill. The protocol started with an inclination of 00 at 8 km.h⁻¹ for female and 10 km.h⁻¹ for male skiers. The speed was increased 1 km.h⁻¹ every minute. When the speed reached 15 km.h⁻¹ the inclination was increased 1.5% every minute. The test was maintained until the athletes are exhausted. The highest heart rate value during the test was measured and used as HR_{max}. For assessing heart rate (HR), Polar Accurex heart rate monitors were used (Polar Electro, Finland).

To evaluate the level of anaerobic capacity a 30 s Wingate test was conducted using a

modified cycle ergometer (model 834E, Monark, Sweden). The test was preceded by a 2-minute warm-up with a load of 1Wxkg⁻¹, and several 5 s accelerations. Subjects performed Wingate test against a resistance equivalent to 0.075 kg.kg⁻¹ body mass. Also skiers were instructed to begin pedaling as fast as possible against the ergometer's inertial resistance and verbally encouraged to continue to pedal as fast as they could for the entire 30 seconds. Results of test were calculated and recorded in watts (W) and watts per kilogram body weight (W/kg-1).

The 2-km time trial was performed on asphalt. Each skier used the same pair of roller-skis at pre-to post-test. These roller-skis were not used between pre-to post-test to avoid changes in rolling resistance. Skiers were allowed to practice with roller-skis for 15-minute during warm-up period. Test started at 30-second intervals, and allowed to use only skate technique. Time was recorded using photocell gates (Power Timer New Test).

Collection of Data

The skiers were instructed to perform the intervals with their maximal sustainable intensity. Training intervention started with a 20-min warm-up on roller-ski of 60% HR_{max}. All training sessions were performed on roller-ski at height differences 144 m on asphalt. All intervals were carried out with a 15-minute active rest (jogging) periods in between. Training was standardized on the days before pre and post-testing.

Before and after the intervention training period the skiers tested for VO₂max, anaerobic power, and also for 2-km time trial performance. All tests were carried out with >48-hour intervals in between. All subjects used to same type of roller-ski (Pro-Ski C2, Sterners, Nyhammar, Sweden with 80 mm wheel diameter), and each

skiers used their own skating poles, boots and helmets. Free skating technique (V1 and V2) was used during the study. Descriptive measurements (height, weight, age) were obtained before the study.

Analysis of Data

Statistical analysis was processed using Microsoft Excel and IBM SPSS (Ver. 20) statistical software. Mean and standard deviation were calculated for each variable. Wilcoxon Test (2-related samples) was used to determine significant changes from pre-to post-test values. Also percentage change (%) were calculated to detect skiers' improvements from pre-to post-test values. P-value <0.005 was considered statistically significant. All values were listed as pre-to post-test mean (±SD), significant level, and percentage change (%).

RESULTS

Pre-to post-testing changes in VO₂max, anaerobic power, and also 2-km time trial performance are shown in Table II and Table III, for female and male skiers, respectively. Within the both female and male skiers group, all parameters were significantly higher during all post-test trials (p<0.005).

These increases were 5.2% (54.9±3.07; 57.8±2.99) and 5.39% (63.4±3.07; 66.9±2.82) for VO₂max, 7.94% (7.68±0.88; 8.29±0.76) and 10.3% (10.1±0.77; 11.2±0.67) for maximum anaerobic power, 3.08% (5.84±0.78; 6.02±0.73) and 4.6% (7.39±0.58; 7.73±0.45) for average anaerobic power in female athletes and male athletes, respectively (Table 1 and 2).

Also 8-week of roller-ski aerobic HIT decreased 2-km time trial performance from 17.3±2.15 to 16.6±0.88 (4.16%) and 13.5±2.15 to 12.6±1.11 (6.47%) in female and male skiers, respectively (Table 1 and 2).

Table 1. Comparison Between Pre and Post Test in Female Athletes

Parameters	PRE	POST	p	%
	X±SD	X±SD		Change
VO ₂ max(ml.kg.dk ⁻¹)	54.9±3.07	57.8±2.99	0.012*	5.32
HR _{max} (beats.min ⁻¹)	187.8±9.5	184.8±8.7	0.011*	-1.60
Max Anaerobic Power (Watt.kg ⁻¹)	7.68±0.88	8.29±0.76	0.012*	7.94
Average Anaerobic Power (Watt.kg ⁻¹)	5.84±0.78	6.02±0.73	0.726	3.08
2-km time trial (sn)	17.3±2.15	16.6±0.88	0.012*	-4.16

* p<0.05

Table 2. Comparison Between Pre and Post Test in Male Athletes

Parameters	PRE	POST	p	%
	X±SD	X±SD		Change
VO ₂ max(ml.kg.dk ⁻¹)	63.4±3.07	66.9±2.82	0.005*	5.39
HR _{max} (beats.min ⁻¹)	185.9±13.24	181.4±12.76	0.005*	-2.42
Max Anaerobic Power (Watt.kg ⁻¹)	10.1±0.77	11.16±0.67	0.005*	10.28
Average Anaerobic Power (Watt.kg ⁻¹)	7.39±0.58	7.73±0.45	0.037*	4.6
2-km time trial (sn)	13.5±2.15	12.6±1.01	0.005*	-6.47

* p<0.05

DISCUSSION

This study demonstrated 8-week of aerobic high-intensity interval training with roller-ski enhanced aerobic and anaerobic power, and also 2-km time trial performance in both female and male skiers. These improvements were 5.2% and 5.39% for VO₂max, 7.94% and 10.28% for maximum anaerobic power, 3.08% and 4.6% for average anaerobic power in female athletes and male athletes, respectively. Our findings suggest that the roller-ski aerobic high-intensity interval training within the preparation session can induce performance increases in aerobic and anaerobic power

independently of the order or gender of such exercises.

Previous studies have reported that adding two interval sessions per week for 4 to 8-week improves performance by 2% to 4% among well-trained endurance athletes [17]. Several studies have reported that similar effects of aerobic high-intensity endurance training on performance and aerobic characteristics [19]. Parallel with earlier findings [12, 15, 19], it can be said that high-intensity aerobic interval training has significant effects on VO₂max in cross-country skiers. McGawley and al. [2013] [20], analyzed the influences of block interval trainings in junior cross-country skiers; they found an increase in VO₂max by

3%. Seiler et al. [2010] [17] compared the effects of a 32 minutes interval training program [MHR %90] and 16 minutes interval training program [MHR%94] on performance in recreational cyclists. After 7-week intervention period they reported that significant improvements were seen in 32 minutes interval training group. Similarly Helgerud and et al. [2007] [21], stated that high-intensity endurance interval training compared to low intensity trainings [70% HR_{max}] is significantly more efficient in VO₂max improvement. According to present study roller-ski aerobic high-intensity interval training can be specified to have positive effects on aerobic capacity improvements. Future studies should need to further explore this topic.

With the start of using the skating technique, importance of upper body anaerobic capacity stated by several studies [10, 22]. Vesterinen et al. [2009] [23], found that high-anaerobic capacity was linked to good performance in the first heats of sprint competition. In a study on anaerobic power in well-trained cross-country skiers, Nillson et al [2004] [24], showed that 6 week of upper-body interval training, 3 times a week, significantly increases maximum anaerobic power and minimum anaerobic power. Our results suggest that the aerobic high-intensity interval training with roller-ski promote increases in anaerobic capacity in cross-country skiers. This finding corroborate that of Sharp et al [1986] [25], who reported that high-intensity sprint training has significant influences in anaerobic energy production and power production. To understand the importance of the aerobic and anaerobic capacity in sprint skiing is still need more research [9].

The improvement in sprint performance was observed in both groups. A potential

explanation for these findings could be due to the fact that increased aerobic and anaerobic power. Furthermore, previous studies reported that the higher training speeds during intervention periods might be cause of improved sprint performance [15, 26]. One of these studies by Sandbakk et al [2011] [15], found that intervention group improved sprint performance [1.5-km] 13-second after 8-week high-intensity intervention period in elite junior cross-country skiers. In this study, skiers improved 2-km time trial performance by 0, 72-second and 0, 67-second in female and male skiers, respectively. These small improvements may partly be explained by distance length and level of skiers.

RECOMMENDATION

This study has shown that aerobic and anaerobic power was increased during the pre-season by a specific training program based on roller-ski uphill intervals at high intensity. However, this study shows that improvements in time-trial performance. So, this training model might be useful for both coaches and athletes to enhance VO_{2max} and anaerobic power. With reference to the training effects found in our study, we suggest that the skiers should integrate the roller-ski uphill aerobic high-intensity intervals in their training programs. More studies are needed to evaluate the roller-ski uphill interval trainings in cross-country skiers. Additionally, future studies are needed to carry on with a control group in order to detect differences between all groups.

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