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# Effect of Aerobic High-Intensity Interval Training on $VO_{2max}$ and Anaerobic Power in Cross-Country Skiers

İmdat Yarim[1], Ebru Çetin[1] and Bahar Ateş Keleş[2]

*1. Faculty of Sport Science, Gazi University, Ankara 06330, Turkey*

*2. Faculty of Sport Science, Uşak University, Uşak 64000, Turkey*

**Abstract:** The purpose of this study was to investigate whether eight weeks of aerobic high-intensity interval training with roller ski is effective in cross-country skiers. 10 male (age, 18.28 ± 2.1 years; height, 171.26 ± 4.12 cm; weight 61.39 ± 6.28 kg) and 8 female (age, 16.05 ± 0.3 years; height, 158.3 ± 6.47 cm; weight, 49.34 ± 0.7 kg) junior cross country skiers completed the study. All skiers performed a 2 × 2-km all-out uphill intervals with roller-skis, 3 times a week, in addition to their traditional training program. Measurements included $VO_{2max}$ (maximal oxygen uptake), anaerobic power, and also for 2-km roller ski. 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 roller ski performance were significantly higher during all post-test trials in all groups ($P < 0.005$). With reference to the training effects found in our study, 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:** Cross-country skiing, $VO_2$max, anaerobic power, interval training.

## 1. Introduction

During the pre-season, athletes' training emphasizes aim to improve physical and physiological qualities [1]. Cross-country skiing is a physiologically demanding endurance sport [2-5]. However, in recent years, the nature of cross-country skiing has changed, a new skiing style (called skating) has become popular and followed by several new competition formats such as pursuit, mass start and sprint have been introduced [2, 6, 7]. Following these changes, various fitness components, balance, coordination, aerobic and anaerobic endurance, power and strength, require for success [5].

Skiers compete different types of terrain at widely varying speeds. Therefore, physical and technical abilities are determining factors for skiers and also they need to alter their rate of work and techniques during a ski race [8]. Thus, fitness development through training is a complex process that includes an increase strength, power [4, 5, 9] maximal oxygen consumption ($VO_{2max}$) and time to exhaustion and lactate threshold [3].

Traditionally, endurance athletes have trained according to approach of high volumes of low-intensity and moderate volume of high-intensity endurance training. Cross-country skiers normally use this training approach (called polarized model) in their training [10, 11]. Endurance training has always been the major method [2] and the off-season involves a highly percentage of the annual training hours for cross-country skiers. Also the off-season is a vital training period to improve skiers' performance. Skiers commonly use running and roller-ski trainings in these months [3]. Recently, high intensity training (HIT) has become popular due to provide rapid aerobic improvements in endurance athletes [12, 13]. Also it is well known that these types of aerobic trainings improve performance in well-trained endurance athletes [10, 12].

The purpose of this study was to determine the effects of a pre-season, aerobic high-intensity roller-ski interval training program. We hypothesized that the

**Corresponding author:** Dr. Bahar Ateş Keleş, Ph.D., assistant professor, research fields: sport science, training science and motor development.

specific program would allow skiers to increase their aerobic and anaerobic capacities and also 2-km time trial performance.

## 2. Materials and Methods

Ten male (age, 18.28 ± 2.1 years; height, 171.26 ± 4.12 cm; weight 61.39 ± 6.28 kg) and 8 female (age, 16.05 ± 0.3 years; height, 158.3 ± 6.47 cm; weight, 49.34 ± 0.7 kg) junior cross-country skiers completed the study. Both written and oral information regarding the possible risk and benefits were given before the study. All skiers signed a volunteer form and gave their written consent prior to their inclusion into the study. All test procedures were performed in accordance with the Declaration of Helsinki 2008, and the study was approved by the Gazi University Medical Faculty Ethical Review Ankara, Turkey. 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 2 × 2-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 min), at 85%-92% of maximal heart rate ($HR_{max}$) with total work period durations of 40-45 min.

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-min 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 $VO_{2max}$, anaerobic power, and also for 2-km roller-ski skating. 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. V1 is used primarily when going uphill. In V1, one double pole push on every second leg push and an asymmetrical load on one side (leading side/hang side/strong side) of the body. V2 is your medium gear when skate skiing. In V2 technique, one double pole push is performed on every leg push. It is often used on moderate inclines or in the transition from uphill to flat terrain. Descriptive measurements (height, weight, age) were obtained before the study.

### *2.1 $VO_{2max}$ Measurements*

$VO_{2max}$ 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 ($VO_2$) and hearth rate (HR) were recorded every 2 min. 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 0 °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).

### *2.2 Anaerobic Capacity Measurements*

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-min warm-up with a load of 1 $W.kg^{-1}$, and several 5s accelerations. Male subjects performed Wingate Test at resistance settings to 0.075 $kg.kg^{-1}$ body mass. Female subjects performed Wingate Test at resistance settings to 0.060 $W.kg^{-1}$ body mass. Also skiers were instructed to begin

pedalling 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 sec. Results of test were calculated and recorded in watts (W) and watts per kilogram body weight ($W/kg^{-1}$).

*2.3 2-km Roller-Ski Measurements*

The 2-km roller-ski skating 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 min during warm-up period. Test started at 30 sec intervals, and allowed to use only skate technique. Time was recorded using photocell gates (Power Timer New Test).

*2.4 Statistical Analysis*

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 changes (%) were calculated to detect skiers' improvements from pre-to post-test values. $P < 0.005$ was considered statistically significant. All values were listed as pre-to post-test mean (± SD), significant level, and percentage changes (%).

## 3. Results

Pre-to post-testing changes in $VO_{2max}$, anaerobic power, and also 2-km time trial performance are shown in Tables 1 and 2, 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% (54.92 ± 3.07 $ml.kg^{-1}.min^{-1}$; 57.84 ± 2.99 $ml.kg^{-1}.min^{-1}$) and 5.39% (63.43 ± 3.07 $ml.kg^{-1}.min^{-1}$; 66.85 ± 2.82 $ml.kg^{-1}.min^{-1}$) for $VO_{2max}$, 7.94% (7.68 ± 0.88 $W.kg^{-1}$; 8.29 ± 0.76 $W.kg^{-1}$) and 10.28% (10.12 ± 0.77 $W.kg^{-1}$; 11.16 ± 0.67 $W.kg^{-1}$) for max anaerobic power, 3.08% (5.84 ± 0.78 $W.kg^{-1}$; 6.02 ± 0.73 $W.kg^{-1}$) and 4.6% (7.39 ± 0.58 $W.kg^{-1}$; 7.73 ± 0.45 $W.kg^{-1}$) for average anaerobic power in female athletes and male athletes, respectively (Tables 1 and 2).

Also 8-week of roller-ski aerobic HIT decreased 2-km roller skiing performance from 17.3 ± 2.15 sec to 16.58 ± 0.88 sec (4.16%) and 13.45 ± 2.15 sec to 12.58 ± 1.11 sec (6.47%) in female and male skiers, respectively (Tables 1 and 2).

**Table 1 Comparison between pre and post-test in female athletes.**

| Parameters | Pre-Test | Post-Test | *P* | % |
|---|---|---|---|---|
| | x ± s | x ± s | | Change |
| $VO_{2max}$ ($ml.kg^{-1}.min^{-1}$) | 54.92 ± 3.07 | 57.84 ± 2.99 | 0.012* | 5.32 |
| $HR_{max}$ ($beats.min^{-1}$) | 187.75 ± 9.5 | 184.75 ± 8.7 | 0.011* | -1.60 |
| Max Anaerobic Power ($Watt\text{-}kg^{-1}$) | 7.68 ± 0.88 | 8.29 ± 0.76 | 0.012* | 7.94 |
| Average Anaerobic Power ($Watt\text{-}kg^{-1}$) | 5.84 ± 0.78 | 6.02 ± 0.73 | 0.726 | 3.08 |
| 2-km roller-ski (sec) | 17.3 ± 2.15 | 16.58 ± 0.88 | 0.012* | -4.16 |

**Table 2 Comparison between pre and post-test in male athletes.**

| Parameters | Pre-Test | Post-Test | *P* | % |
|---|---|---|---|---|
| | x ± s | x ± s | | Change |
| $VO_{2max}$ ($ml.kg^{-1}.min^{-1}$) | 63.43 ± 3.07 | 66.85 ± 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 ($Watt\text{-}kg^{-1}$) | 10.12 ± 0.77 | 11.16 ± 0.67 | 0.005* | 10.28 |
| Average Anaerobic Power ($Watt\text{-}kg^{-1}$) | 7.39 ± 0.58 | 7.73 ± 0.45 | 0.037* | 4.6 |
| 2-km roller-ski (sec) | 13.45 ± 2.15 | 12.58 ± 1.01 | 0.005* | -6.47 |

## 4. Discussion

This study demonstrated 8-week of aerobic high-intensity interval training with roller-ski improved aerobic capacity, anaerobic capacity, and also 2-km roller skiing in female and male cross-country skiers. These improvements were 5.2% and 5.39% for $VO_{2max}$, 7.94% and 10.28% for max anaerobic power, 3.08% and 4.6% for average anaerobic power in female athletes and male athletes, respectively. Our findings suggest that the aerobic high-intensity interval training with roller-ski within the preparation session can induce performance increases in aerobic and anaerobic capacity 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 [13].

Several studies have reported that similar effects of aerobic high-intensity endurance training on performance and aerobic characteristics [14]. Parallel with earlier findings [10, 11, 14], this study reported that high-intensity aerobic training is effective for improving $VO_{2max}$ in cross-country skiers. It can be advantageous for endurance performance to slightly reduce intensity and use longer duration of intervals in endurance athletes [10]. McGawley and at al. [15], analyzed the influences of block interval trainings in highly-trained junior cross-country skiers; they found an increase in $VO_{2max}$ by 3%. Seiler et al. [13] compared the effects of a 32 min interval training program (MHR 90%) and 16 min interval training program (MHR 94%) on performance in recreational cyclists. After 7-week intervention period, they reported that significant improvements were seen in 32 min interval training group. Similarly Helgerud and et al. [16] stated that high-intensity endurance interval training compared to low intensity trainings (70% $HR_{max}$) is significantly more efficient in $VO2_{max}$ improvement. According to present study, aerobic high-intensity interval training with roller-ski can be specified to have positive effects on aerobic capacity improvements. Future studies should need to further explore this topic.

With the advent of the skating technique, the importance of upper body anaerobic capacity is stated by several studies [17, 18]. Vesterinen et al. [7] 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. [19] 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. [20], who reported that high-intensity sprint training has significant influences in anaerobic energy production and power production. However, more research is needed to understand the importance of the aerobic and anaerobic capacities in sprint skiing [11].

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 it might also be induced by higher training speeds during intervention periods performed as roller-ski in level terrain [11, 21]. One of these studies by Sandbakk et al. [11] found that intervention group improved sprint performance (1.5-km) 13-sec after 8-week high-intensity intervention period in elite junior cross-country skiers. In this study, skiers improved 2-km roller-ski performance by 0.72-sec and 0.87-sec in female and male skiers, respectively. These small improvements may partly be explained by distance length and level of skiers.

## 5. Conclusion

With reference to the training effects found in our

study, we suggest that the skiers should integrate the roller ski aerobic high-intensity intervals models in their training programs. This topic has not yet been fully resolved by the literature and is therefore subject for continuous discussions. The applications from this study apply both for coaches and scientists by showing that $VO_{2max}$ and anaerobic power can be improved both by adding roller ski aerobic high-intensity interval sessions with a long duration at a higher intensity. The fact that the longer duration intervals additionally enhanced endurance performance and the anaerobic capacity is an important finding for practice.

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