Exercise Capacity Improvements Over Three Months Training: How Can we Relate Medium Term Training Results in A Competitive Roller Skiing Event?

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ABSTRACT

An adapted aerobic – anaerobic training ratio can improve short term VO₂peak but can limit long-term improvements aerobic and the anaerobic threshold changes. Twelve (n=12) international competitive male cross-country (G₁) and biathlon athletes (G₂) with a median age of 23 (21–27) years old were included as study subjects. Two VO₂max tests (n=2) were conducted in the study period (93 days), further approached as test 1 (T₁) during day 1 and test 2 (T₂) during day 93. Several training sessions were conducted over 3,800 km volume. Lack of changes regarding VT₁–VT₂ group values were obtained between T₁–T₂ tests. Yet, through an individual approach, both high aerobic (p=0.03, r=0.62, CI95%=0.04 to 0.89) and low aerobic training (p=0.04, r=-0.65, CI95% = -0.90 to -0.03) were correlated with VT in G₂. No similar results were obtained in G₁ training group (p>0.05). Volume training, unlike early high intensity training, induces changes over the athletes’ exercise capacity. Aerobic training will induce an improved relative oxygen consumption, while both aerobic and anaerobic training can increase peak VO₂ value, when implemented during the following 30-60 training days.

Introduction

During recent competitive activities, several questions are raised regarding the athletes’ exercise capacity and training methodology. Training activity is constantly adapted based on both volume and effort intensity changes. However, several papers had an objective to improve and generate new over coming data regarding individual exercise capacity and training methodology improvements but few concluded new outcomes [1-3]. By comparing two different training methods, this study is not an experimental one. Conducting an experimental training methodology can be difficult in competitive senior athletes over an Olympic year, as described in our case. Starting from several relevant results [2,4] training periodization is the main long term influence factor over both cross country skiing and roller skiing performance due to continuous physiological training induced changes. Of particular importance is the lack of change over the last 15 – 20 years over individual maximal or sub maximal testing results, whereas performance has improved significantly by doubling the average speed in different stages and competitive activities [5]. Unlike other endurance sports, such as running, classic roller skiing induces a higher VO₂peak and VO₂max ratio, over sub-techniques, which involve a lower muscle mass use [6]. Hoogsteen et al. [7] confirmed that excess cardiac output can be measured in cross country ski and roller ski training. However, based on Sandbakk et al. [8] outcomes, the performance will benefit from VO₂max value, which reaches up to 15% differences over both classical (diagonal stride, double poling with a kick, double
poling and herringbone) and skating skiing (G
2, G
3, G
4, G
5) [5]. The technique is permanently adapted over the training or competition track profile, inducing frequent changes in effort intensity.

Exercise capacity is described by a greater oxygen uptake as seen in several papers, which used different training methodologies over endurance athletes [9]. According to Guth et al. [10] an enhanced cardio pulmonary capacity will represent the basic training foundation, while various factors will relate the final training or competition outcome. Along training, the main objective is to prepare the athlete for the pre competition phase in which high intensity effort will occur. Both pulmonary system, oxygen uptake and transport along cardiovascular output and skeletal muscles will influence individual performance. From a physiological perspective, pulmonary gas exchange will follow normal O
2 saturation and blood pH values, whereas limiting in some cases aerobic power over physical effort. According to Holmberg et al. [11], both static and dynamic lung volumes can reach 5 to 20% improvement over training while an increased cardiovascular output will improve regulation over vascular conductance Calbet et al. [12]. As a result, the main training objective will follow similar physiological improvements, whereas Sandbakk Ø et al. [5] believe that the ability to transform metabolic energy efficiently into speed is a key determinant of performance.

General cross-country ski training consists of 700 – 850 hours of annual training, whereas more than 75% of the volume is attributive to low intensity effort, 5 – 15% to moderate intensity and 5 – 10% to high intensity effort. Even if general training data described a high aerobic volume, suggestive information over individual performance seems to relate that an improved performance is seen by conducting both moderate and high intensity effort during all season. The volume attribute to each training stage is rather adapted from one athlete to another. Further on based our hypothesis an adapted aerobic – anaerobic training ratio, with an enhanced aerobic and low anaerobic volume can improve short term VO
2max but limit long-term effect over both aerobic and anaerobic thresholds while reducing performance or relating lack of progress. Therefore our objective is to initiate several VO
2 measurements and a median training monitoring period to test the current hypothesis by performing a day by day training performance analysis.

Material and Methods

A cross sectional study was conducted over June – September 2017, as representing the 2017 – 2018 season general training period. To take part and publish the current results we obtained the University Ethical Committee approval along both the athletes and the Federal Management acceptance.

Participants

To be included as study subjects, the individuals had to fulfil the following criteria: (I.) male cross country ski, roller ski or biathlon athlete, (II.) >18 years old, (III.) currently competing at professional national or international level (IV.) along general medical acceptance. Due to lower age (<18 years old) two individuals (n=2) were excluded from the study group. Twelve (n=12) competitive male cross country and biathlon athletes (n=5 vs. n=7) with a median age of 23 (21 – 27) years old were included as study subjects. As part of the methodology, the biathlon athletes were included in sample 1 (G
1), while the roller skiing athletes were included in sample 2 (G
2). The two samples (G
1 and G
2) followed a different training program over 93 days, as part of the general 2017–2018 roller skiing training season. The main differences between G
1 and G
2 were related to both volume and exercise intensity. As a result sample 1 (G
1) reached 3500 km volume, while sample 2 (G
2) training volume was 4500 km over the study period (93 days). In both G
1 and G
2 groups, individual volume differences (±15%) were measured.

Measures

Two VO
2max tests (n=2) were conducted in the study period. The first test (T
1) was conducted during day 1 of 93 days, whereas the second test (T
2) was conducted over day 93 of 93. Over the training period, several training sessions were conducted at a temperature monitored between +10 and +20°C, over a median training volume of 3.800 km (G
1 + G
2). In the following training intensity guidance: low aerobic training (80%), high aerobic training (15%) and anaerobic training (5% of VO
2max). As illustrated in Figure 1, the athletes took part in a competitive 15 km roller skiing competition, as to conclude individual performance over three months training period.

Figure 1: Study protocol illustration detailing P
1 – P
3 training period.
Maximal oxygen consumption test (VO₂max)

The VO₂max tests (T₁) were conducted by applying the Bruce Maximal Testing Protocol. [13] The test was conducted through Cosmed Quark CPET equipment (Rome, Italy) and Cosmed T150 (Rome, Italy) running treadmill, during seven (n=7) different effort stages. Each stage lasted three minutes. The first testing stage (stage 1) consisted of 2.7 km speed, 5 METS, and 10% grade, while over the last stage (stage 7), a maximum running speed of 9.6 km/h, 20 METS and 22% grade was reached. The testing time depended on the athletes’ exercise capacity. Prior the VO₂max analysis, the athletes performed a 20 minutes warm up, reaching 50-85% of HRmax. The main device was calibrated before each test with know O₂ (16%) and CO₂ (4%) concentrations, while the flow meter was calibrated in the start of each test.

During T₁ and T₂ test, the following parameters were assessed: VO₂max (relative maximum oxygen consumption, ml/kg/min), VT₁ (aerobic ventilatory threshold, b/min), VT₂ (anaerobic ventilatory threshold, b/min) along with VE (Ventilation, L/min), VCO₂ (carbon dioxide production, ml/min), VE/VCO₂ (ventilatory equivalents for oxygen, ml/min), PetO₂ (end-tidal oxygen tension, mmHg) and PetCO₂ (end-tidal carbon dioxide tension, mmHg). Using VO₂max test data, the following training zones were confirmed through the V slop method [14]: Warm up aerobic zone, Training Zone 1, (Z₁ 45-65%); Aerobic zone, Zone 2 (Z₂ 66-80%); High Aerobic, Zone 3 (Z₃ 81-87%); Anaerobic, Zone 4 (Z₄ 88-93%) along Anaerobic Power, Zone 5 (Z₅ 94-100%) similar to Seiler and Tonnessen [15].

Effort intensity was used to confirm the athletes’ training objective. Anthropometric measurements were conducted before each test, including both body weight (kg) and height (cm), by using a calibrate scale.

Training Monitoring

Over the study period, 186 training sessions were analysed by using Global Positioning Systems, Polar V800 (Kempele, Finland), and Polar H7 Bluetooth Monitor (Kempele, Finland), as monitoring: training time (hh:mm:ss), distance (kilometres, km), heart rate (HR, b/min; % of HRmax), positive (+Dif, meters) and negative altitude gain (-Dif, meters).

15 km Skating Roller Skiing Test Course

During day 93, the athletes took part in a 15 km competitive activity. The action was held over a 4 km track placed +1300 m above sea level, with a positive gain of 148 meters and a negative gain of 69 meters per lap. The test consisted of 3.75 laps, 555 m positive difference and 258.75 m negative difference gain. The start between athletes was programed at 30 seconds intervals.

Statistical Analysis

GraphPad Prism 5.0 software was used for statistical analysis. The Standard Deviation (SD), the coefficient of variation (CV%), along with the median (median) value were used in the descriptive analysis. During the inferential statistics, D’Agostino Pearson omnibus normality test was used to obtain data normalization, while the Spearman test was applied in order to identify a correlation between two different parameters. One sample t test was used to assess the differences between T₁ and T₂ test parameters, while Kruskal-Wallis test was applied in order to measure the evolution over P₁ – P₃ training period. We considered a p value<0.05 as being statistically significant, with a standard Confidence Interval set at 95% (CI95%). T₁ and T₂ cardiopulmonary differences were analysed as a positive or a negative percentage (+/- %) from the maximum value measured in either of the two tests. The statistical analysis was conducted by using individual G₁ and G₂ samples, or by using a single sample (G₁ + G₂) to evaluate the main exercise capacity changes, based on training differences.

Results

During T₁, median body (72 vs. 73.6 kg) and height (176 vs. 175 cm) were similar in both G₁ and G₂ samples (p>0.05).

Athlete Training Data

Of the training volume, strength training was performed over 10.25% (409.28 minutes) whereas Trail Running 23.03% (875.14 km), Nordic Walking, 2.33% (88.54 km), Road Cycling, 17.53%, (666.14 km), Classic Roller skiing (10.83%, 411.54 km) and Free Roller skiing (35.75%, 1358.5 km) were monitored as main training activities in the main study group of G₁ and G₂. During 197.73 hours training the study group reached a median volume of 3.500 km and 4.500 km (G₁ vs. G₂) distance. Of the volume, High Intensity Training (HIT) was conducted over 3.5% (122.5 vs. 157.5 km) in G₁ vs. G₂. High aerobic training reached 11.63% (407.05 vs. 157.5 km) in G₁ vs. G₂. Over the training period several differences were monitored between G₁ and G₂ as illustrated in Table 1. The main training differences were used as performance improvement indicators.

Table 1: Descriptive data over the P₁ – P₃ training period.

| Training data | P₁ | P₂ | P₃ | Significant difference over 3 months training? (p value) |
|---------------|----|----|----|--------------------------------------------------------|
| G₁ | G₂ | G₁ | G₂ | G₁ | G₂ | G₁ | G₂ | |
| **Time, min** | 4092 | 4237 | 3908 | 4543 | 2787 | 3894 | 0.009** | 0.29* |
| **Distance, km** | 830 | 1024 | 835.7 | 887.9 | 609,7 | 715.7 | 0.008** | 0.10* |
Positive difference gain, meters & 15.715 & 11.46 & 16.035 & 14.76 & 15.105 & 12.01 & 0.28* & 0.10* \\
Negative difference gain, meters & 15.815 & 11.973 & 22.053 & 10.798 & 11.75 & 10.918 & 0.55* & 0.65* \\
Z5, % & 0 & 3 & 0 & 2 & 1 & 2 & 0.10* & 0.17* \\
Z4, % & 0.5 & 7 & 15 & 9 & 2 & 5 & 0.02** & 0.28* \\
Z3, % & 16.5 & 29 & 6 & 15 & 2.5 & 11 & 0.09** & 0.13* \\
Z2, % & 43.5 & 31 & 32.5 & 41 & 34 & 26 & 0.40* & 0.10* \\
Z1, % & 38.5 & 25 & 59 & 28 & 6.5 & 53 & 0.28* & 0.11* \\

Note: P1 = training period 1 between day 1 and day 30, P2 = training period 2 between day 31 and day 60, p = probability level, p < 0.01**, p < 0.05, Z5 = anaerobic power training zone, Z4 = Anaerobic training zone, Z3 = High aerobic training zone, Z2 = Low aerobic training zone, Z1 = Warm up zone.

Relative VO2max changes over T1 - T2 training period

The median group VO2 value was significantly different during T2 unlike T1 measurement (69.23 vs. 79.29 ml/min/kg). The median group difference reached +8.86 ml/kg/min over T2 as against T1 result (p = 0.01). However, no significant differences (p>0.05) were monitored during T2 between G1 and G2 test results (Table 2). VO2 changes over T1 test were correlated to the training volume (p = 0.02, r=0.67, CI95%=0.119 to 0.906). The volume difference between the two samples was 22.3% in G2 vs. G1 (4500 vs. 3500 km) associating changes in peak VO2max value over G2 vs. G1 during T2 test (80.01 vs. 78.89 ml/min/kg). A higher volume along a positive difference gain in G1 (+13.430 m) was significantly correlated to VO2 (p=0.01, r=0.69, CI95%=0.91 to 0.15). Over training specificity, during P1 - P2 period, Cycling (20% vs. 30%) (p=0.02), Nordic walking (0 vs. 5%) (p = 0.019, r = -0.68, CI95% = -0.91 to -0.15) was significantly correlated to VT in G1, where carbon dioxide output was significantly correlated to VT in G1 (p = 0.027, r = -0.65, CI95% = -0.90 to -0.09). However, high aerobic training during P2 was significantly correlated to VO2 and VE/VO2 (p = 0.03, r = 0.64, CI95% = 0.07 to 0.08), while positive (p = 0.0482) and negative (p = 0.0496) difference gain were correlated to VO2 (p = 0.027).

Table 2: Comparative data regarding VO2 and VT changes over T1 and T2 tests.

| Main Analysis | G1 | G2 | Statistical p value regarding T1 over T2 differences |
|---------------|----|----|-----------------------------------------------------|
| VO2, ml/min/kg | 69.45 | 78.8 | 11.87% | 68.12 | 80.01 | 14.87% | 0.95* |
| VT,% of HRmax | 83.01 | 78.79 | -5.09% | 78.14% | 78.28 | 0.18% | 0.15* |
| VT,% of HRmax | 98.95 | 97.11 | -1.86% | 97.29% | 96.13 | -12.0% | 0.10* |

Note: G1 = sample 1, G2 = sample 2, T1 = VO2max test 1 over day 1, T2 = VO2max test 2 over day 63, VT1 = ventilator threshold 1, VT2 = ventilator threshold 2, p = probability level, p < 0.01**, p < 0.05, VO2 = maximum rate of oxygen consumption.

Ventilatory Threshold Improvement Over T1 - T2 Training Period

Lack of changes among VT1 - VT2 group values (G1 + G2) were obtained between T1 - T2 tests. Yet, through an individual approach both high aerobic (p = 0.03, r = 0.62, CI95% = 0.04 to 0.89) and low aerobic training (p = 0.04, r = -0.65, CI95% = -0.90 to -0.03) were correlated with the VT in G2. No similar results were obtained in G1 training group (p=0.05) as seen in Table 3. High aerobic training volume (>5%) was significantly correlated to VT1 (-2.94%) during P1 stage. As a result, both high aerobic (p = 0.020) and low aerobic (p = 0.026) training intensity were significantly correlated to VT1. As a result, minimum changes during T2 vs. T1 test results are confirmed through +0.18% vs. -5.09% in G1 vs. G2. Even though there were no significant (p>0.05) differences in VT2 values (T1 vs T2), the changes between the two tests (-1.23%) were related to other training outcomes. Among them, the anaerobic training volume was significantly correlated to VT2 values over T2 outcomes (p = 0.05, r = 0.87, CI95% = 0.56 to 0.96). Unlike volume, training intensity was of particular importance over both P1 - P2 periods, as illustrated in Table 3. P1 and P2 training volume was significantly correlated with VT1 (p=0.001). Over P2, both the number of training sessions (p = 0.39, r = -0.65, CI95% = -0.90 to -0.04) and anaerobic training volume was significantly correlated (p = 0.046) to further VT changes. Yet, VT1 measurement was significantly correlated to VO2 values (p = 0.01, r = 0.92, CI95% = 0.71 to 0.97).
Table 3: Training intensity influence, during P1 - P2 period, over T2 results (G1 and G2).

| Proposed Parameters | Statistical Results |
|---------------------|---------------------|
| Parameter 1 | Median Value | Parameter 2 | Median group value | p | r | CI95% |
| | | | | | | Upper | Lower |
| VT1 | 81.48% of HRmax | Distance, km | 3537 | 0.98* | -0.005 | -0.6 | 0.59 |
| | | Training time, min | 18.864 | 0.71* | -0.12 | -0.67 | 0.51 |
| | | Z5, % | 1 | 0.03** | 0.64 | 0.06 | 0.89 |
| | | Z4, % | 3.5 | 0.03** | 0.64 | 0.06 | 0.89 |
| | | Z3, % | 14 | 0.02** | 0.68 | 0.14 | 0.91 |
| | | Z2, % | 35 | 0.02** | -0.66 | -0.9 | -0.1 |
| | | Z1, % | 46.5 | 0.04** | -0.61 | -0.88 | 0.02 |
| VT2 | 98.06% of HRmax | Distance, km | 3537 | 0.37* | -0.29 | -0.76 | 0.36 |
| | | Training time, min | 18.864 | 0.28* | -0.35 | -0.78 | 0.31 |
| | | Z5, % | 1 | 0.02** | 0.67 | 0.12 | 0.9 |
| | | Z4, % | 3.5 | 0.04** | 0.61 | 0.03 | 0.88 |
| | | Z3, % | 14 | 0.07** | 0.55 | -0.06 | 0.86 |
| | | Z2, % | 35 | 0.62* | -0.16 | -0.69 | 0.48 |
| | | Z1, % | 46.5 | 0.11* | -0.5 | -0.84 | 0.13 |

Note: VT1 = ventilator threshold 1, VT2 = ventilator threshold 2, p = probability level, p = < 0.01**, *p < 0.05, r = Pearson product-moment correlation coefficient, CI95% = confidence interval of 95%, Z5 = anaerobic power training zone, Z4 = Anaerobic training zone, Z3 = High aerobic training zone, Z2 = Low aerobic training zone, Z1 = Warm up zone.

Competitive, High Intensity Effort Analysis

Track time was significantly correlated to the training outcomes. As a result, anaerobic – aerobic training ratio was significantly correlated to individual performance, as illustrated through average pace in Table 4. Over P1 - P2 period, anaerobic training was correlated to the average pace unlike aerobic training which showed no significant relationship to individual performance. Further on, except for effort time, no correlations were obtained between P3 training and individual performance (p>0.05).

Table 4: Training intensity influence over high intensity roller skiing effort in the study group (G1 and G2).

| Proposed Parameters | Statistical Results |
|---------------------|---------------------|
| Parameter 1 | Median Value | P1 - P2 period | Median Group Value | p | r | CI95% |
| | | | | | | Upper | Lower |
| Average pace | 2.26 min/km | Distance, km | 841.6 | 0.358* | -0.29 | -0.74 | 0.33 |
| | | Training time, min | 4022 | 0.895* | 0.04 | -0.54 | -0.74 |
| | | Z5, % | 1 | 0.003** | -0.77 | -0.93 | -0.35 |
| | | Z4, % | 2 | 0.002** | -0.78 | -0.93 | -0.37 |
| | | Z3, % | 15 | 0.014** | -0.68 | -0.9 | -0.17 |
| | | Z2, % | 36 | 0.678* | 0.13 | -0.47 | 0.65 |
| | | Z1, % | 39 | 0.031** | 0.61 | 0.06 | 0.88 |
| P3 period | Median group value | p | r | CI95% |
| | | | | | | Upper | Lower |
| | | Distance, km | 682.6 | 0.143* | -0.44 | -0.81 | 0.16 |
| | | Training time, min | 3059 | 0.026** | -0.63 | -0.88 | -0.09 |
| | | Z5, % | 2 | 0.627* | -0.15 | -0.67 | 0.45 |
| | | Z4, % | 3 | 0.293* | -0.33 | -0.76 | 0.3 |
| | | Z3, % | 7.5 | 0.123* | -0.46 | -0.82 | 0.14 |
| | | Z2, % | 29.5 | 0.754* | 0.1 | -0.5 | 0.63 |
| | | Z1, % | 60.5 | 0.374* | 0.281 | -0.34 | 0.73 |
Note: $P_1$ = training period 1 between day 2 and day 30, $P_2$ = training period 2 between days 31 and 60, $P_3$ = training period 3 over days 62 – 92, $r$ = Pearson product-moment correlation coefficient, CI 95% = confidence interval of 95%, $p = $ probability level, $* = p< 0.05$, ** = $p< 0.01$, $Z_5$ = anaerobic power training zone, $Z_4$ = Anaerobic training zone, $Z_3$ = High aerobic training zone, $Z_2$ = Low aerobic training zone, $Z_1$ = Warm up zone

**Discussion**

Following the study outcomes, effort capacity was improved in $G_2$ unlike $G_1$ sample. The main improvements were related to both training intensity and volume whereas $G_1$ training methodology focused on both high aerobic and anaerobic training volume, while improving effort capacity over $G_2$ training methodology, which focused on high aerobic and low anaerobic volume. Based on the current findings the questions raised are related to the athletes’ exercise capacity development and metabolism adaptation in $G_1$ and $G_2$, as studied earlier by Sandbak et al. [5], over both general and specific training.

**Exercise Specificity**

Roller skiing and biathlon exercise is performed by using similar techniques, characterised through an increased oxygen consumption and power output [16-18]. According to Hartmann et al. [4] several differences can be observed between cross country and biathlon training periods. The differences are related to training volume and intensity, due to shooting in one as against other activity. Yet, training technique will be similar. Training specificity seems to influence effort capacity based on both $G_1$ vs. $G_2$ performance and training outcome. Further on, Cycling, Trail Running and Nordic Walking were included as training methods in our paper, imposing an improved effect over individual performance, as against Solli et al. [2] which failed to obtain improvements in individual performance based upon non-specific training sessions. During $P_3$, in $G_2$ unlike $G_1$, non-specific training methods along specific skating roller skiing resulted on an improved aerobic capacity as against classic roller skiing sessions. This approach is different to Stögg et al. [19] who obtained an improved overall performance over classic technique training. The differences between the two methods are related to exercise intensity by influencing oxygen demand, optimal tissue oxygenation and metabolism adaptation over comparative low intensity training periods [20].

**Training Methodology**

Two training methods, known as the threshold-training and the polarized training [21] were used in the study methodology. Of them, the threshold training was conducted near $VT_2$, whereas the polarized training either under or above, but not near $VT_2$ as described earlier by Stögg et al. [22]. Threshold training, specific applied in $G_2$ sample, improved effort capacity, as against $G_1$ polarized training program which consisted high volume of low aerobic activity (55 – 75% of $VO_{2max}$). Physical effort capacity improvements were related to both changes in volume and high intensity training, as shown in $G_2$ unlike $G_1$ whereas both $VO_{2peak}$ and $VO_{2max}$ along $VT_1$ and $VT_2$ improved in $G_2$, unlike $G_1$. Comparing both the $VO_2$ change and the competition outcome, we can observe an improper anaerobic exercise staging, which influenced both $VE$, $PetO_2$ and relative $VO_2$ value, similar to Patel et al. [23] results, which programed both anaerobic and aerobic training over a medium training period. However, during 93 days training period, low aerobic training was correlated to a drop in exercise capacity as seen in $G_1$ as against $G_2$.

Aerobic power has been considered of particular importance in individual performance. As a result, the pulmonary system, along the maximum cardiac capacity, oxygen transport and skeletal muscle can influence the final outcome. As we have seen in $G_1$ training methodology, aerobic training reached 80% of the volume, similar to Seller et al. [21] training methodology, while encountering differences regarding anaerobic training volume. In Soli and Kjerland paper (2006) [21], 5 to 10% of the volume was held between $VT_1$ and $VT_2$, whereas 15-20% of the volume increased over $VT_1$ intensity. One similar training method, published by Stögg et al. [19] improved exercise capacity based on anaerobic power development, as against our training methodology, in which an enhanced performance resulted of a well-adapted low - high aerobic and anaerobic effort. However, we believe that excessive sympathetic stress cannot be totally confirmed through the HR monitoring systems, and therefore important training recovery data could be unknown.

Soli et al. [2] confirmed that general aerobic power is related to high aerobic training, opposite to $G_1$ training directions and final outcomes. High aerobic training influenced $VT_1$ in $G_2$ while the final competitive result was negatively correlated to high intensity training, limiting high aerobic training volume, whereas improving low aerobic volume over $P_3$, period, without similar results in $P_2$. The average pace during the competitive effort was influenced by both aerobic and anaerobic volume, unlike Ateş et al. [24] outcome which described 10 to 15% high intensity effort (90 - 100% of $VO_2max$). An increased high aerobic training volume was correlated with $VT_1$ increase in $G_2$ unlike $G_1$, but without any influence over individual performance during high intensity effort. As described by Holmberg [25], excess high aerobic training could have imposed excessive sympathetic stress in $G_2$ unlike $G_1$. An important performance drop can be described in such situations due to improper protein synthesis, while inducing cellular stimulation over preserving individual autonomic balance. However, such data was not part of the current paper results.

**Limitations**

Conducting a $VO_{2max}$ test within a group of cross country and biathlon athletes on a running treadmill, can reduce $VO_{2max}$ due to lack of effort specificity, as illustrated by Losnegard et al. [26].
Cross-country skiing will represent a more important specific activity, unlike roller skiing and running. From the available data [27,28], motor-control is obtained through specific training, regardless of the sport. As a result, testing specificity will be of particular importance and if possible, further studies should measure the oxygen relative value by performing a specific cross country ski test, whereas improving the number of athletes and recovery systems, along cardio-pulmonary assessment, muscular fibre recruitment over medium- long term training.

Conclusion

Volume training, unlike early high intensity training, induces changes over the athletes’ exercise capacity. Specific roller skiing activities may have an important role in developing both specific strength and aerobic capacity. However, non-specific activities improved general aerobic capacity, while limiting the technical development of the athlete. Aerobic training will induce an improved relative oxygen consumption, while both aerobic and anaerobic training can impose a greater peak VO₂ value, when implement over the following 30–60 training days. Therefore our hypothesis is confirmed based on the current results which confirmed that anaerobic training improve short term VO₂max values, without a long term effect over both aerobic and anaerobic thresholds. Based on the current outcomes, 80% low aerobic, 15% high aerobic and 5% anaerobic volume facilitated an early effort capacity improvement in G, unlike G₁. Yet, relative oxygen consumption and anaerobic capacity will confirm the actual training capacity, through ventilation, relative oxygen consumption and ventilatory threshold assessment during specific or non-specific testing. Training periodization should sustain an appropriate balance between both volume and intensity training. However, an improved effort capacity should be further assess by using a specific method while using a larger study group.

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Conflicts of Interest

The authors declare no conflict of interest

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