

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 VO_{2max} , but can limit long-term improvements aerobic and the anaerobic threshold changes. Twelve (n=12) international competitive male cross-country (G_1) and biathlon athletes (G_2) with a median age of 23 (21–27) years old were included as study subjects. Two VO_{2max} tests (n=2) were conducted in the study period (93 days), further approached as test 1 (T_1) during day 1 and test 2 (T_2) during day 93. Several training sessions were conducted over 3.800 km volume. Lack of changes regarding VT_1 - VT_2 group values were obtained between T_1 - T_2 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 G_2 . No similar results were obtained in G_1 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 VO_2 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 overcoming 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 VO_{2peak} and VO_{2max} 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 VO_{2max} 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 ($\pm 15\%$) 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.

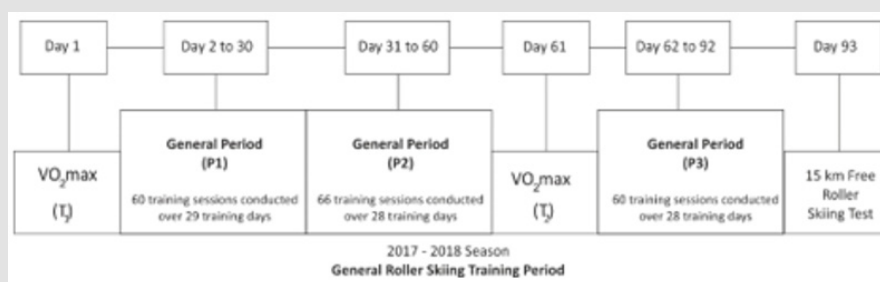


Figure 1: Study protocol illustration detailing $P_1 - P_3$ training period.

Maximal oxygen consumption test (VO_{2max})

The VO_{2max} tests (T_1) 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 VO_{2max} analysis, the athletes performed a 20 minutes warm up, reaching 50-85% of HRmax. The main device was calibrated before each test with known O_2 (16%) and CO_2 (4%) concentrations, while the flow meter was calibrated in the start of each test.

During T_1 and T_2 test, the following parameters were assessed: VO_{2peak} (relative maximum oxygen consumption, ml/kg/min), VT_1 (aerobic ventilatory threshold, b/min), VT_2 (anaerobic ventilator threshold, b/min) along with VE (Ventilation, L/min), VCO_2 (carbon dioxide production, ml/min), VE/VO_2 (ventilatory equivalents for oxygen, ml/min), $PetO_2$ (end-tidal oxygen tension, mmHg) and $PetCO_2$ (end-tidal carbon dioxide tension, mmHg). Using VO_{2max} test data, the following training zones were confirmed through the V slop method [14]: Warm up aerobic zone, Training Zone 1, (Z_1 , 45-65%); Aerobic zone, Zone 2 (Z_2 , 66-80%); High Aerobic, Zone 3 (Z_3 , 81-87%); Anaerobic, Zone 4 (Z_4 , 88-93%) along Anaerobic Power, Zone 5 (Z_5 , 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 T_1 and T_2 test parameters, while Kruskal-Wallis test was applied in order to measure the evolution over P_1 - P_3 training period. We considered a p value<0.05 as being statistically significant, with a standard Confidence Interval set at 95% (CI95%). T_1 and T_2 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 G_1 and G_2 samples, or by using a single sample ($G_1 + G_2$), to evaluate the main exercise capacity changes, based on training differences.

Results

During T_1 , median body (72 vs. 73.6 kg) and height (176 vs. 175 cm) were similar in both G_1 and G_2 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 G_1 and G_2 . During 197.73 hours training the study group reached a median volume of 3.500 km and 4.500 km (G_1 vs. G_2) distance. Of the volume, High Intensity Training (HIT) was conducted over 3.5% (122.5 vs. 157.5 km) in G_1 vs. G_2 . High aerobic training reached 11.63% (407.05 vs. 523.35 km) whereas 83.25% (2.913,75 vs. 3.746,25 km) were conducted over low aerobic training in G_1 unlike G_2 . Over the training period several differences were monitored between G_1 and G_2 as illustrated in Table 1. The main training differences were used as performance improvement indicators.

Table 1: Descriptive data over the $P_1 - P_3$ training period.

Training data	P_1		P_2		P_3		Significant difference over 3 months training?	
	G_1	G_2	G_1	G_2	G_1	G_2	(p value)	
							G_1	G_2
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	1.5	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	29	60.5	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 VO_{2max} 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 T₂ 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 VO_{2max} 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 G₂ (+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)

along skating roller skiing volume (27% vs. 25.8%) were correlated to peak VO₂ value in G₁ vs. G₂. (p = 0.04, r= -0.60, CI95% = -0.88 to -0.01). No significant correlations were obtained over VO_{2peak} and training intensity (p>0.05) during P₁ - P₂ periods, in both G₁ and G₂ samples. Over T₂, VE was significantly correlated to training specificity. As a result, VE was significantly correlated to both classic (6%) and skating roller skiing training (26.5%) during P₁ (p=0.031, r=0.64, CI95% = 0.07 to 0.89). Secondary training activities such as running and cycling failed to influence VE (p>0.05) over T₂ testing, whereas carbon dioxide output was significantly correlated to VT₁ (p = 0.027, r= -0.65, CI95% = -0.90 to -0.09). However, high aerobic training during P₂ was significantly correlated to VCO₂ 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 VCO₂ (p = 0.027).

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

Main Analysis	G ₁			G ₂			Statistical p value regarding T ₂ over T ₁ differences (p value)
	T ₁	T ₂	T ₂ over T ₁ differences	T ₁	T ₂	T ₂ over T ₁ differences	
VO ₂ , ml/min/kg	69.45	78.8	11.87%	68.12	80.01	14.87%	0.95*
VT ₁ , % of HR _{max}	83.01	78.79	-5.09%	78.14%	78.28	0.18%	0.15*
VT ₂ , % of HR _{max}	98.95	97.11	-1.86%	97.29%	96.13	-1.20%	0.10*

Note: G₁ = sample 1, G₂ = sample 2, T₁ = VO_{2max} test 1 over day 1, T₂ = VO_{2max} 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 regarding 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 G₂ vs. G₁. 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 P₁, 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 VT₁ changes. Yet, VT₂ 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
VT ₁	81.48% of HR _{max}	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
VT ₂	98.06% of HR _{max}	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	P ₁ - P ₂ 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
		P ₃ period	Median group value	p	r	CI95%	
		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, CI95% = confidence interval of 95%, 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

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 Sandbakk 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_2 vs. G_1 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_1 , 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 Stöggl 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 Stöggl 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_2 and VO_{2peak} 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_2 training methodology, aerobic training reached 80% of the volume, similar to Seiler et al. [21] training methodology, while encountering differences regarding anaerobic training volume. In Seiler 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_2 intensity. One similar training method, published by Stöggl 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 $P_1 - P_2$ period, without similar results in P_3 . 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_{2peak} 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 VO_2 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 VO_{2max} 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_2 unlike G_1 . 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 asses 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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