Endurance training: changes in aerobic and anaerobic exercise capacity by using an adapted training intensity and volume ratio in cross-country skiers

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Abstract

Background. An adapted aerobic-anaerobic training ratio can either improve or drop short-term VO_{2peak} while limiting the development of aerobic and anaerobic thresholds.

Aims. We aimed to test the exercise capacity by measuring VO_{2peak} while comparing two different training methodologies next to a day-by-day training performance analysis.

Methods. Twelve (n=12) competitive male cross-country and biathlon athletes with a median age of 23 (21–27) years were included as study subjects. Two VO_{2peak} tests (n=2) were conducted in the study period (61 days). The first test (T1) was conducted during day 1 of 61 while test 2 (T_2) was conducted during day 61. Several training sessions were held over a median training volume of 3389.6 km (G_1 and G_2).

Results. Lack of changes regarding the ventilatory thresholds (VT_1 – VT_2) was obtained between T_1 and T_2. Yet, through an individual approach, both high aerobic (p=0.03, r =0.62, CI 95%=0.04 to 0.89) and low aerobic training (p=0.04, r=-0.65, CI 95% = -0.90 to -0.03) were correlated with VT_1 and VT_2 in G_2. No similar results were obtained in the G_1 training group (p>0.05).

Conclusions. Non-specific training activities improved general aerobic capacity while limiting technical development. Aerobic training reduced oxygen uptake at peak exercise, while both aerobic and anaerobic training were related to a greater peak VO_2 value.

Keywords: sports performance, anaerobic training, aerobic training, elite athletes, VO_{2peak}.

Introduction

Training represents the main long-term influence factor of athletic performance during similar events due to continuous physiological induced changes (Solli et al., 2017; Carlsson et al., 2017; Sandbakk et al., 2016a; Coote, 2010; Solli et al., 2019).

Winter endurance sports such as cross-country skiing and biathlon are known to be two of the most physically demanding events. In both sports, the main performances are strongly related to the skiing technique and the exercise capacity (Sandbakk et al., 2014). Differences regarding training activity and overall performances are frequently observed due to overtime changes in oxygen uptake (Solli et al., 2017; Hartmann et al., 2015; Nevil et al., 2003; Guth & Sptephen, 2013; Sagelv et al., 2018), knowing that gross efficiency, sprint ability, and peak oxygen consumption can mainly influence performance, despite differences in the skiing technique. Therefore, recent papers suggest that oxygen uptake can increase up to +15% during the diagonal stride, over double-poling with a kick, double-poling, and herringbone as against V1, V2, and V2-alternate skating skiing technique (Sandbakk et al., 2017). Such differences provide unique movement patterns, which tend to become less obvious in elite athletes, compared to sub-elite athletes.

In endurance sports, physical performance is valued based on oxygen uptake, lactate tolerance, strength, and force along with resistance. Therefore, performance represents the association between pre-existing qualities and training-induced physiological changes (Coote et al.,

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2010; Solli et al. 2019; Laaksonen et al., 2018a; Hoogsteen et al., 2003). Therefore, training activity will have common stage objectives such as improving the technique, the endurance capacity along specific or general muscle strength and resistance (Sandback et al., 2017). Physical and physiological performances are usually related to pulmonary gas exchange following normal O_2 saturation and blood pH values, whereas limiting in some cases maximum oxygen uptake (VO_{2max}) and therefore performance. However, both static and dynamic lung volumes can reach up to 20% improvements (Holmberg & Calbet, 2007) next to changes in cardiovascular output, which can enhance regulation over vascular conductance (Calbet et al., 2015), and therefore performance through training.

Early studies focused on cross-country skiing (Welde et al., 2017; Stöggl et al., 2018; Carlsson et al., 2014; Vernillo et al., 2019) or biathlon (Laaksonen et al., 2018b; Luchsinger et al., 2018; Luchsinger et al., 2019; Müller & Liu, 2018; Sandbakk et al. 2016b; Tønnessen et al., 2014; Stöggl & Sperlich, 2015). Based upon the differences referred to, general cross-country ski training consists of 700 - 850 hours of annual training, involving endurance, strength, and speed seasons while maintaining high-intensity training activities. Of the volume, more than 75% is attributive to low-intensity training, 5 – 15% to moderate intensity, and 5 – 10% to high-intensity physical training (Stöggl & Sperlich, 2015). Yet, based on the exercise intensity zones, more than 15% of the training time is attributed to high-intensity exercise while low intensity is combined with both strength and speed training to maintain muscle mass and sprint ability (Solli et al., 2017). Further, the volume attribute to each training stage is rather different from one athlete to another. Yet, it is generally accepted that aerobic training will be dominant.

Suggestive data reveal different results following both moderate and high-intensity training. Based on various research results, low-intensity training can negatively influence performance during high-intensity activity. During early times, Tabata et al. (1996) proved that low training intensity can reduce speed and power output as against anaerobic exercise during competition. Therefore, the main outcome is usually related to negative changes in both muscle metabolism, muscle fiber density, and cardiac performances. However, there is a lack of details regarding endurance training. Many papers studied new overcoming data regarding exercise capacity and the training methodology (Sandbakk et al., 2014; Sandbakk et al., 2017; Schmitt et al., 2018). Of them, few studies concluded new outcomes (Solli et al., 2017; Carlsson et al., 2017; Sandbakk et al., 2014; Holmberg, 2015; Sandbakk et al., 2013; Vergès et al., 2006; Badawy & Muaidi, 2019) due to short to medium term training analysis. Yet, how many coaches will follow a 90% aerobic training plan, whereas obtaining high speed and resistance during the competition phase? Based on our hypothesis an adapted aerobic – anaerobic training ratio can improve short-term VO_{2peak} while reducing long-term performance by lack of anaerobic development. Our study aim is to test the exercise capacity by measuring VO_{2peak} while comparing two different training methodologies next to a day-by-day training performance analysis.

Material and method

Research protocol

We conducted a prospective observational analytical research study during June-September 2017, representing the 2017-2018 season general training period. The study methodology was applied in compliance with the human research criteria, as set out in the Helsinki Declaration. To take part and publish the current results we obtained the University Ethical Committee approval (No. 27/01.08.2017), next to both the athletes' and the national athlete federation acceptance.

a) Period and place of the research

Part of the procedures, tests, and measurements was performed in the Advanced Medical and Pharmaceutical Research Center (CCAMF) of "George Emil Palade" University of Medicine, Pharmacy, Science and Technology of Târgu Mureş, Romania.

b) Subjects and groups

To be part of the research, the following inclusion criteria were applied: general medical acceptance, male cross-country ski/biathlon athlete, at least 18 years old, currently competing in professional national or international level.

Twelve competitive male cross-country and biathlon athletes (n = 5 vs. n = 7) were included in the research study (23, 21 to 27 years old). Due to lower age (<18 years old), two participants (n = 2) were excluded from the study group. As part of the study methodology, sample 1 (G_1) consisted of biathlon athletes and sample 2 (G_2) consisted of cross-country ski athletes. The two samples (G_1 and G_2) followed a different training program during 61 days, as part of the general 2017-2018 training period.

The training differences between G_1 and G_2 samples were related to exercise volume and intensity. Sample 1 (G_1) conducted: 1.66, 8.5, and 89.5% high intensity, moderate intensity, and low-intensity volume respectively, over 1.665 km distance. Sample 2 (G_2) followed a higher intensity training program, consisting of: 9.66, 19.6, 70.6% high intensity, moderate intensity, and low-intensity training, over 1.911,9 km distance. In both G_1 and G_2 study samples, individual volume differences were measured (±15%).

c) Applied tests

Two maximum oxygen consumption tests (VO_{2peak}) were conducted during the study period (Fig. 1). The first test (T_1) was performed during day 1 of 61, whereas the second test (T_2) was performed during day 61. During the training period, multiple training sessions were performed at +10°C and +20°C temperatures, over a median training volume of 3.389,6 km (G_1 and G_2), as further detailed.

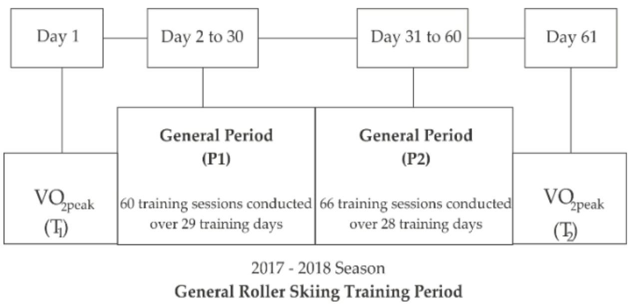

Fig. 1 - Study protocol illustration detailing P_1 - P_3 training period.

Anthropometric measurements took place before each VO_{2peak} test. During this stage, the weight (kg) and height (cm) of the athletes was measured by using the ADE, GmbH M30404-01 calibrated thaliometer (Germany).

Peak Oxygen consumption during the incremental test (VO_{2peak})

VO_{2peak} (T_1 and T_2) was measured upon Bruce Maximal Testing Protocol (Badawy & Muaidi, 2019) by using Cosmed Quark CPET equipment (Rome, Italy) and Cosmed T150 (Rome, Italy) running treadmill, over nine intensity stages (n=9). The CPET device was calibrated before each test with known O_2 (16%) and CO_2 (4%) concentrations, along with the flow meter.

Before the VO_{2peak} measurement, the athletes performed 20 minutes (min) warm-up, reaching 50-85% of HR_{max}. Each testing stage (n=9) lasted 3 minutes. The first testing stage (stage 1) consisted of 2.7 km speed, and 10% grade, while over the last testing stage (stage 9) the athletes reached a maximum running speed of 12.07 km/h and 28% grade. The testing time depended on the athletes' exercise capacity. We validated the tests by using one to several criteria: respiratory exchange ratio (RER) >1.10, ±10 b/min of the predicted HR_{max} *and/or ≤150 mL O_2*/min changes at the end of the test (Martin & Hadmas, 2019).

During the testing, some parameters were carefully monitored. Of them, we measured $VO_{2peak,}$ (oxygen uptake at peak exercise, ml/kg/min), VT_1 (aerobic ventilatory threshold, b/min), VT_2 (anaerobic ventilatory threshold, b/min) along with VE (min ventilation, L/min), VCO_2 (carbon dioxide production, ml/min), VE/VO_2 (ventilatory equivalents for oxygen, ml/min), $PetO_2$ (partial end-tidal oxygen tension, mmHg) and $PetCO_2$ (partial end-tidal carbon dioxide tension, mmHg).

Peak Oxygen consumption during the incremental test (VO_{2peak}) - Training intensity zones

By using the VO_{2peak} test and by applying the V-slope method(34), a five training zone model (n=5) was created for each athlete. The method is commonly used to identify the ventilatory threshold (VT) during progressive exercise testing. Therefore, we determined the exercise intensity zones as "below-, at-, above-" the VT_2 and VT_1 (Beaver et al., 1986; Dolezal et al., 2017): Warm-up aerobic zone, Training Zone 1, (TZ_1, usually stated between 45-65% of VO_{2peak}); Aerobic zone, Training Zone 2 (TZ_2, usually stated between 66-80% of VO_{2peak}); High Aerobic, Training Zone 3 (TZ_3, usually stated between 81-87% of VO_{2peak}); Anaerobic, Training Zone 4 (TZ_4, usually stated between 88-93% of VO_{2peak}) along with Anaerobic Power, Training Zone 5 (TZ_5, usually stated between 94-100% of VO_{2peak}), similar to Seiler & Tønnessen (2016).

Training monitoring

We monitored the daily training to confirm the athletes' training intensity and training volume. During the study period, we analyzed 186 training sessions by using a Global Positioning System: Polar V800 (Kempele, Finland) and Polar H7 heart rate Bluetooth Monitor (Kempele, Finland), to measure: training time (hh:mm: ss), distance (kilometers, km), heart rate (HR, b/min; % of HR_{max}), positive (+Dif, meters) and negative altitude gain (-Dif, meters).

d) Statistical processing

GraphPad Prism 5.0 software was used for statistical analysis. The standard deviation (SD), coefficient of variation (CV%), and median values were used in the descriptive analysis. D`Agostino Pearson omnibus normality test was used to obtain data normalization. Spearman test was applied to identify a correlation between two exercise-related parameters. *Mann Whitney Test* was used to assess the differences between T_1 and T_2 test parameters, while the Wilcoxon rank test was applied to measure the progress over training methodology. 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 analyzed 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 the training differences.

Results

Median body weight (72 vs. 73.6 kg) and body height (176 vs. 175 cm) were similar in both G_1 and G_2 samples (p>0.05) during T_1 measurement.

Training results

During 139.08 hours of training, the athletes covered a median volume of 1.665,7 (G_1) and 1.911,9 (G_2) km. The training volume consisted of 1.75% high-intensity exercise (HIT) in G_1 unlike G_2 (29.14 km vs. 286.78 km). Moderate intensity exercise reached 10.28% (171.32 vs. 477.97 km) whereas 93% of the volume (1.469,3 vs. 1.145,2 km) was conducted in low exercise intensity as seen in G_1 unlike G_2 (Table I). Additional data are illustrated in Table I, which shows the comparative results between G_1 and G_2 training activity, obtained by applying the Wilcoxon signed-rank statistical test.

Of the training volume, 10.23% was attributed to *strength training* (14.22 hours) whereas *trail running* reached 23.83% (852.89 km). *Nordic walking*, 2.80% (100.17 km), *road cycling*, 17.20% (615.34 km), *classic roller skiing*, 11.47% (410.35 km) along with *free roller skiing,* 34.09% (1219.6 km) were part of the study group training program ($G_1 + G_2$).

Relative VO_{2peak} changes over T_1 - T_2 training period

During T_2 and T_1 measurements, the median VO_{2peak} group value was significantly different (69.23 vs. 79.29 ml/min/kg). The difference reached +8.86 ml/kg/min during T_2 as against T_1 value (p = 0.01) (Table II). Additional data are illustrated in Table 2, which presents the statistical differences between T_2 and T_1 regarding the VO_{2peak} measurements in both G_1 and G_2 samples. The data from Table II. was analyzed by using the Mann-Whitney Test.

Exercise training characteristics and cardio-pulmonary changes

VO_{2peak} improved during T_2 measurement due to both training volume (p = 0.02, r=0.67, CI 95%=0.119 to 0.906) and positive difference gain (p=0.01, r=0.69, CI 95%= 0.91 to 0.15). No less than 22.3% was the volume difference between the two samples while remarking a higher positive difference gain in $G_{2,}$ unlike the G_1 sample. So on, training volume next to training altitude gain seem to improve VCO_2 (p = 0.03, r = 0.64) and VE/VO_2 (p = 0.028, r = 0.78) during T_2 test in G_2 unlike G_1.

Table I
Descriptive data regarding the training activity

Training data		P_1		P_2		The significant difference over 2 months of training			
						p-value	Sum of signed ranks (W)	p-value	Sum of signed ranks (W)
		G_1	G_2	G_1	G_2	G_1	G_2	G_1	G_2
Time (min)		4092	4237	3908	4543	0.57	8.00	0.01	-49.00
Distance (km)		830	1024	835,7	887.9	0.29	-14.00	0.41	17.00
Positive difference gain (m)		15.715	11.460	16.035	14.760	0.03	-26.00	0.18	-27.00
Negative difference gain (m)		15.815	11.973	22.053	10.798	0.01	28.00	0.35	19.00
High intensity	TZ_5, %	0	33	00	2	1.00	-1.00	0.00	55.00
	TZ_4, %	0.5	77	1.5	9	0.02	-21.00	0.53	13.00
Moderate intensity	TZ_3, %	17	29	6	17	0.03	26.00	0.10	33.00
Low intensity	TZ_2, %	44	36	32.5	43	0.21	16.00	0.00	-55.00
	TZ_1, %	38.5	25	59	29	0.09	-21.00	0.01	-36.00

Table II
Comparative data regarding VO_{2peak} and VT changes betweenT_1 and T_2 tests.

Main analysis		G_1			G_2			Statistical p-value regarding T_2 over T_1 differences (p-value)	
		G_1	G_2	T_2 over T_1 differences	G_1	G_2	T_2 ove T_1 differences	p value	Mann-Whitney U
VO_{2peak} (ml/min/kg)		9.45	78.8	+11.87%	68.12	80.01	+14.87%	0.95	304
T_1	% of HR_{max}	3.01	78.79	-5.09%	78.14	78.28	+0.18%	0.15	288
	L/min	3.15	3.55	+10.70	3.19	3.77	+18.46%	0.00	54
	ml/min/kg	44.79	49.55		43.07	51.23			
T_2	% of HR_{max}	98.95	97.11	-1.86%	97.29	96.13	-1.2%	0.10	336
	L/min	4.62	4.92	+5.87	4.90	5.41	+10.67%	0.10	90
	ml/min/kg	66.59	70.09		65.98	73.20			

Table III
Training intensity during P_1 - P_2 period and T_2 improvements (G_1 and G_2)

Proposed parameters				Statistical results				
Parameter 1	Median Value	Parameter 2		Median group value	p	r	CI95%	
							Upper	Lower
VT_1	3.73 L/min	Distance (km)		1789	0.16	-0.44	-0.83	0.23
		Training time (min)		8345	0.16	-0.45	-0.83	0.21
		High intensity volume	TZ5, %	0.75	0.05*	0.41	-0.02	0.71
			TZ4, %	2.75	0.03	0.45	0.02	0.74
		Moderate intensity volume	TZ3, %	18.25	0.00	0.69	0.36	0.86
		Low intensity volume	TZ2, %	37.25	0.62*	0.10	-0.33	0.51
			TZ1, %	41	0.00	-0.65	-0.84	-0.30
VT_2	5.22 L/min	Distance (km)		1789	0.95*	-0.01	-0.62	0.60
		Training time (min)		8345	0.91*	0.03	-0.58	0.63
		High intensity volume	TZ5, %	0.75	0.08*	0.54	-0.09	0.86
			TZ4, %	2.75	0.00	0.75	0.25	0.93
		Moderate intensity volume	TZ3, %	18.25	0.00	0.89	0.61	0.97
		Low intensity volume	TZ2, %	37.25	0.65*	0.10	-0.34	0.51
			TZ1, %	41	0.00	-0.67	-0.85	-0.33

During P_1 to P_2 training period, low-intensity training activities such as *Nordic walking (p=0.019, r=-0.68)* and *skating roller skiing (p=0.04, r=-0.60)* improved T_2 VO_{2peak} measurement in G_2 as against G_1. A higher classic (6%) and skating roller skiing (26.5%) training volume was related to VE during T_2 measurement (p=0.031, r=0.64) as against running and cycling training sessions (p>0.05).

Non-significant results were obtained regarding VO_{2peak} changes and P_1 along with P_2 training intensity (p>0.05). Both VT values changed during P_1 and P_2 training periods. An 8.28% average improvement was measured in G_1 next to 14.56% in G_2. Following the training data from G_2 sample, both moderated (p = 0.03, r = 0.62) and low intensity training volume (p = 0.04, r = -0.65) were correlated with the VT. Yet, during P_1 and P_2 training stage, the moderated training intensity volume (>5%) was significantly correlated with the VT_1 heart rate value in G_1 (- 2.94%). Further on, based on G_2 data, high-intensity training volume was significantly correlated to VT_2 during the T_2 test (p = 0.05, r = 0.87), as further seen in Table III. whose data illustrate the main changes in VT based on P_1 and P_2 training stages obtained by applying the Spearman test.

During both P_1 and P_2 stages, training volume was significantly correlated with VT_1 (p = 0.001). Yet, over the P_1 training stage, both the number of training sessions and the higher intensity training volume were significantly correlated to further VT_1 differences between the two samples (p = 0.039, r = - 0.65). Specifically, VT_2 value was significantly correlated to VO_{2peak} measurement during T_2 test (p = 0.01, r = 0.92, CI 95% = 0.71 to 0.97).

Discussion

This paper studied low intensity and high-intensity training activities and their role in exercise capacity. In the current study, VO_{2peak} was most improved in the higher training intensity sample. Overall changes in exercise capacity are a result of both training intensity and volume. More specifically, G_2 followed both moderated and high-intensity training volume while improving VO_{2peak} next to VT point as against G_1 training methodology, which consisted of low to moderate exercise intensity. However, differences were recorded in training volume.

Studies show that skiing speed is responsible for more than 60% of the competition performance (Welde et al., 2017; Stöggl et al., 2018; Bolger et al., 2015; Haugnes et al., 2019). However, the complexity of what is called *performance* is far from being solved. Athletes' performance is related to many factors, such as cell metabolism during submaximal and maximal exercise, oxygen consumption, muscle fiber type along with specific or general strength. All of the numbers and the qualities which reflect exercise capacity are necessary to improve power and resistance during a specific exercise while increasing the movement speed (Stöggl et al., 2018; Carlsson et al., 2014; Luchsinger et al., 2019; Bolger et al., 2015; Seiler & Kjerland, 2006).

Training methodology

Two training methods, known as threshold training and polarized training (Seiler & Kjerland, 2006) were used in the study methodology. Of them, the threshold training was conducted near VT_2, similar to Sandbakk et al. (2013) whereas the polarized training was either under or above, but not near VT_2, as described by Stöggl & Sperlich (2015). Other papers applied similar training methods with different outcomes. Billat (2001) described an improved performance due to aerobic training, whereas Vandbakk et al. (2017) obtained a drop in performance. Therefore, the literature results vary with the study group, individual exercise capacity, and the training period.

Following our results, threshold training was specifically applied in the G_2 sample and resulted in an improved exercise capacity, as against the G_1 polarized training program, which consisted of high volume and low-intensity training (55 – 75% of VO_{2peak}).

The positive effects of high-intensity exercise training on endurance performance have been demonstrated repeatedly (Andersson, 2016) while the long-term effect is not discussed. In the current paper, the main changes in exercise capacity were related to both training volume and intensity, as shown in G_2 by changes seen in VO_{2peak}, along VT_1 and VT_2. By comparing the changes in VO_2, we can observe an improper anaerobic exercise staging that influenced VE, $PetO_2$, and relative VO_2 value, similar to Patel et al. (2017). However, low aerobic training was correlated with negative performances as seen in G_1, unlike G_2 over the training period. Similar results were reported by Milanović et al. (2015) in a different training stage. Yet, the outcome could be explained based upon a low anaerobic capacity, low speed, and resistance during exercise that exceeds VT_2.

Aerobic power is important in athletic performance (Bellar et al., 2015). Studies on biathlon athletes of both sexes show an improved overall resistance(12) due to maximum VO_{2peak} of> 80 and> 65 mL • kg-1 • min-1, respectively (Tønnessen et al., 2015). Following G_2 training methodology, 80% of the training volume was conducted within the aerobic intensity zones, similar to Seiler & Kjerland (2006) training methodology, while encountering differences regarding anaerobic training volume. In Seiler & Kjerland paper (2006), 5 to 10% of the volume was held between VT_1 and VT_2, whereas 15-20% of the volume was set over VT_2 point. One similar training method was applied by Stöggl & Björklund (2017). In their paper, exercise capacity was improved by changes in the anaerobic training zones. Yet, this result differs from our main outcome through which an enhanced performance is a result of an adapted low-high aerobic and anaerobic ratio. Solli et al. (2017) confirmed that maximum oxygen consumption is related to high aerobic training, opposite to G_1 training. High aerobic exercise intensity changed VT_1 in G_2. However, we must take into account that lack of changes in oxygen uptake does not necessarily indicate the lack of performance. Thus, several papers published similar oxygen uptake values with changes in lactate accumulation, unlike our paper, which did not include lactate analysis. Somewhat similar, Ateş & Cetin (2017) applied a high intensity and a high training volume. In their study, HIT training reached between 10 and 15% of the volume, as against 5-10% volume applied in our training methodology. Following our study results, VO_{2peak} increased in G_2, unlike G_1, next to VT_1 due to high aerobic training. As described by Holmberg et al. (2007), excess aerobic training could have imposed excessive sympathetic stress in G_2, unlike G_1. Important changes in performance can be seen in similar situations over improper protein synthesis, through cellular stimulation over preserving individual autonomic balance. However, such data were not part of the current paper results.

Physical exercise specificity

According to Hartmann et al. (2015) differences can be observed between cross-country and biathlon ski training. However, in both cross-country and biathlon activities, roller skiing is conducted on a similar technique (Starczewski et al., 2019; Stöggl et al., 2011; Stöggl et al., 2017). As a result, the differences between the two events are much more related to the training volume and the training intensity, along with shooting in one as against other activities.

Exercise technique is similar, even if training specificity will influence individual exercise capacity, as seen in G_2 unlike G_1 with a reported lower non-specific training volume (Solli et al., 2017; Sandbakk et al., 2017; Sandbakk, 2018). As seen in our results, *cycling*, *trail running,* and *nordic walking* improved individual performance, as against Solli et al. (2019) outcomes which failed to report changes in exercise capacity based upon non-specific training sessions. However, it is generally recognized that speed and maximal strength are related to specific movements (Prieske et al., 2018). Yet, few papers used non-specific methods to improve the aerobic volume or to analyze the athletes' recovery process between the training sessions. Many of the published papers focused on obtaining or maintaining high speed through specific training while improving individual techniques. However, we measured changes in VT_1 through nonspecific training methods, which reached 54.05% of the volume. Of course, the volume resulted from the training plan, which was adapted according to the environmental conditions (Fuente et al., 2011).

During P_1, non-specific training methods next to roller skiing resulted in an improved aerobic capacity as against classic roller skiing sessions in G_2. This approach is different from Stöggl et al. (2019), which obtained an improved overall performance by using more of the specific classic technique as against other techniques or training methods. The differences between the two techniques are generally related to the oxygen demand, optimal tissue oxygenation, and metabolism activity during comparative low intensity training periods (Hartmann et al., 2015). Therefore, classic technique as against skating technique is known to be more intensive, statement, which further describes a higher training intensity, as against other training methods, as seen in G_2, unlike G_1.

Conducting a VO_{2peak} test within a group of cross country and biathlon athletes on a running treadmill can sub estimate VO_{2peak} due to lack of exercise specificity, as illustrated by Losnegard & Hallén (2014). Cross-country skiing will represent a more specific activity, unlike roller skiing and running. From the available data (Fuelscher et al., 2012; Stöggl et al., 2015), 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 peak oxygen relative value during a specific cross-country ski/ roller ski test, whereas increasing: the number of athletes, data use over the recovery periods, along cardio-pulmonary assessment and muscular fiber recruitment during a medium – long term training period. Further research should focus on respecting the training intensity will using different control variables. Of them, lactate production, power output, heart rate may have a different outcome over individual exercise capacity. Such a hypothesis is supported by the current results while taking into account that different outcomes can be obtained while measuring the above-mentioned variables during a short-medium training period, on a control-study group methodology.

Conclusions

1. Low to moderate training intensity induces changes over the athletes' exercise capacity, unlike early high-intensity training which may have the opposite effect. 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 probably limiting the technical development of the athlete.
2. Low-intensity training lowered oxygen uptake at peak exercise, while both medium and high-intensity training induced a greater peak VO_2 value. Therefore, our hypothesis is confirmed based on the current results, which demonstrate that anaerobic training improves short-term VO_{2peak} values, without a long-term effect over both aerobic and anaerobic thresholds.
3. Based on the current outcomes, 80% low aerobic, 15% high aerobic, and 5% anaerobic volume increased exercise capacity in G_2 unlike G_1.
4. Training periodization should aim for an appropriate balance between both volume and intensity training. However, relative oxygen consumption during submaximal exercise and anaerobic capacity should be further on assessed by using a specific method over a larger study group.

Conflicts of interest

The authors declare no conflict of interest.

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