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ORIGINAL STUDIES

Non-specific maximal testing results, under certain training conditions, can be associated with roller skiing performances during a competitive 5K event

Rezultatele testării nespecifice, la efort maximal, pot fi asociate cu performanța sportivului, pe parcursul unui efort maximal specific de 5 km

Ștefan Adrian Martin [1], Roxana Maria Hadmaş [2], Dan Dobreanu [1]
[1] *Physiology Department, University of Medicine and Pharmacy Târgu Mureș, Romania*
[2] *Community Nutrition and Food Hygiene Department, University of Medicine and Pharmacy Târgu Mureș, Romania*

Abstract

Background. Cardiopulmonary analysis, through VO_2max testing, can represent the basis of training development.

Aims. Our aim was to demonstrate that non-specific VO_2max testing can provide important information regarding cardiopulmonary adaptation and its influence over a specific maximal exercise.

Methods. The study group consisted of 8 male XC skiers with international competitive results. During day 1, one single VO_2max test (T1) was conducted, assessing cardiopulmonary capacity and training periodization over day 1 to day 24. On day 24, the athletes competed in a specific 5k roller skiing event (T2), confirming individual exercise capacity, based on T1 measurements: VO_2max, VE, $PetO_2$, $PetCO_2$, VE/VO_2, RER.

Results. Between T1 – T2, all training sessions were monitored. An increased VT_1, during T1 analysis, was related to the maximal HR during T2 (p=0.001). Both VT_1 (p=0.03) and VT_2 values (p=0.03) were correlated with the median pace during T2. During T1, the $PetCO_2$ was significantly correlated with the VCO_2 determined value (p=0.001), relating an improved CO_2 removal rate.

Conclusions. Unlike $PetCO_2$ effects on T2 performances, through $PetO_2$ analysis, no similar results were found. Over T1, an increased aerobic activity was correlated to an improved pace and effort time during the T2 exercise. Increased VE values, along with VO_2 and VE/VO_2 generated an improved $PetCO_2$ ratio and athletes' performance, through an enhanced oxygen extraction, resulting in an improved T2 time, due to an increased aerobic power, stated in T1.

Keywords: elite, training, performance, exercise capacity

Rezumat

Premize. Analiza cardio-pulmonară, prin testarea maximală la efort, poate reprezenta un punct de pornire pentru dezvoltarea, formarea și periodizarea antrenamentului sportiv. Aceasta poate permite aprecierea formei sportive la un moment dat.

Obiective. Obiectivul nostru a fost să demonstrăm că testarea VO_2max, în asocierea unui efort nespecific, poate oferi informații importante cu privire la capacitatea la efort, adaptarea individuală și evoluția în asocierea efortului maximal specific.

Metode. Grupul de studiu a fost alcătuit din 8 schiori fondiști, cu practică sportivă internațională. Prin metodologia de studiu, a fost monitorizat antrenamentul sportiv pe parcursul a 24 de zile. În ziua 1 a fost desfășurată o testare maximală VO_2max (T1), cu scopul de a determina capacitatea la efort și a iniția programarea antrenamentului sportiv între zilele 2-23. În ziua 24, prin intermediul un efort specific, probă de 5 km role, stilul liber, denumit T2, a fost confirmată capacitatea la efort și principalii parametrii evolutivi analizați în T1, prin VO_2max, VE, $PetO_2$, $PetCO_2$, VE/VO_2, RER.

Rezultate. Între T1 și T2, toate perioadele de pregătire au fost monitorizate. Creșterea VT_1, în asocierea analizei T1, a influențat semnificativ evoluția FCmax pe timpul T2 (p = 0.01). Valorile VT_1 (p = 0.03) și VT_2 (p = 0.03) au fost corelate cu viteza de deplasare, în timpul T2. Astfel, în asocierea T1, $PetCO_2$ a fost semnificativ corelat cu valoarea determinată VCO_2 (p = 0.01), stabilind un raport îmbunătățit de eliminare a CO_2.

Concluzii. Spre deosebire de efectele $PetCO_2$ asupra performanțelor T2, prin analiza $PetO_2$, nu s-au identificat rezultate similare. Peste rezultatele T1, efortul preponderent aerob a fost corelat cu îmbunătățirea performanței în asocierea T2. Valorile crescute VE, alături de VO_2 și VE / VO_2, au generat un raport $PetCO_2$ îmbunătățit, respectiv o creștere a performanței sportivilor printr-o extracție de oxigen îmbunătățită, rezultând un timp T2 îmbunătățit.

Cuvinte cheie: elită, antrenament, performanță, capacitate la efort

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Address for correspondence: University of Medicine and Pharmacy, Târgu Mureş, Gheorghe Marinescu Str. No.38, 540139, Romania
E-mail: martinstefanadrian@gmail.com
Corresponding author: Martin Ștefan Adrian, martinstefanadrian@gmail.com

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Introduction

Competitive cross-country skiing can reflect different qualities of athletes based on the distance and the course profile**.** As a result, several differences can be identified regarding the performance of an athlete, between short and long distance events (Sandbakk et al., 2011; Bolger et al., 2015).

The athletic potential can be described through functional analysis during different effort stages. As a result, the muscle fiber type, capillary density along with mitochondrial capacity will influence muscle efficiency. During a prolonged effort, skeletal muscle activity can be characterized through the anaerobic threshold value, the athletes' ability to maintain oxygen consumption, VO_2 performance and the maximum volume of oxygen (Stellingwerff & Spriet, 2014). From a practical point of view, while defining the effort capacity, all the mentioned factors will influence the performance during a specific competitive effort (Joyner & Coyle, 2008).

High intensity training (HIT) represents a well-known method which is implemented in all sports, whether they are team, individual or endurance sports (Buchheit & Laursen, 2013). Training as a winter sports endurance athlete requires a comprehensive aerobic capacity (Tønnessen et al., 2015). Therefore, aerobic training should be predominant during the general training stages, with a transition to anaerobic effort during pre-competitive specific activity. The anaerobic capacity development is associated with both maximum oxygen consumption (VO_2max) and increased anaerobic threshold (AT). Yet, performance differences seem to be related to a well-planned anaerobic capacity, as against an increased maximum oxygen consumption development (Sandbakk & Holmberg, 2014; Hébert-Losier et al., 2017).

An alternative training method involves a volume reduction by increasing effort intensity (Stöggl & Sperlich, 2015). HIT activity seems to generate similar functional adaptations to those obtained as a result of aerobic specific training (Stöggl & Müller, 2009). Among them, metabolic markers, endothelial vascular activity and cardiopulmonary improvements, along with morphological and skeletal muscle metabolism changes, have similar adaption results for the two training methods, under certain recovery conditions (Lundgren et al., 2015).

Hypothesis

Cardiopulmonary analysis, through VO_2max testing, can represent the basis of the training development and periodization. Training analysis will reflect the individuals' ability to perform a maximal effort under specific conditions. Therefore, through the implemented methodology, our objective will be to demonstrate that non-specific VO_2max testing can provide important information regarding the cardiopulmonary adaptation and its influence over a specific maximal effort. Based on similar changes between the specific and non-specific tests, we will try to relate the cardiopulmonary results to the specific maximal test performances, as a result of a pre-determined training program.

Material and method

Research protocol

The study is an observational cross-sectional one, during the 2017-2018 general training period. The following methodology was implemented after obtaining the athletes' acceptance to participate, and the University's Ethical Committee approval to conduct the study.

a) Period and place of the research

The study was conducted between June - July 2017, in Brasov, Romania, where the athletes' training center was found.

b) Subjects and groups

The study group consisted of 8 male cross country skiers with international competitive activity. In order to be included in the study group, clinical medical acceptance was mandatory. The medical consent was aimed at confirming that the athlete was clinically fit to be included in an organized training program.

c) Tests applied

A complete training analysis was conducted over 24 days. The program was initiated at the start of the general roller skiing training stage, in the absence of a specific skiing climate. The training temperatures were stated between 15-20°C.

During the analyzed period (24 days), one single VO_2max test (T1) was conducted on day 1. Following the maximal test (VO_2max, T1), we initiated a training program between day 2 and day 23, closing the analysis with a specific classic roller skiing test (T2), on day 24, as shown in Fig. 1.

Fig. 1 – The study protocol, detailing the training, recovery and testing periods over 24 days

- Maximal exercise testing (VO_2max)

One VO_2max test (T1) was performed by applying the Bruce Maximal Testing Protocol on a running treadmill. The testing took place 48 hours after the last training session. As part of the testing protocol, food intake was standardized 48 hours before the maximal test at 8.6 g/kg carbohydrates, 1.9 g/kg protein and 1.2 g/kg fat.

The cardiopulmonary test was performed using Cosmed Quark CPET (Rome, Italy) equipment, Cosmed F150 Ergometer (Rome, Italy) and Polar H7 Bluetooth CardioFrequency Meter. The equipment calibration took place at the start of each test with known O_2 (16%) and CO_2 (5%) concentrations. The flow meter was calibrated at the start of each test using a Cosmed Syringe (3L). Based on the paper objective, different functional categories were used to describe the athletes' exercise capacity. Among them, relative VO_2 (oxygen volume, ml/min/kg) and absolute VO_2 (oxygen volume, ml/min), VT_1 (ventilatory threshold 1, b/min), VT_2 (ventilatory threshold 2, b/min), VE (ventilation, L/min), VE/VO_2 (ventilatory equivalent for oxygen, ml/min) and VE/VCO_2 (ventilatory equivalent for carbon dioxide, ml/min) were included as performance parameters. The respiratory frequency

(Rf, b/min) along with VT (tidal volume, L/min), VCO_2 (carbon dioxide production, ml/min), $PetO_2$ (end-tidal oxygen tension, mmHg), $PetCO_2$ (end-tidal carbon dioxide tension, mmHg), HR_{max} (maximum heart rate, b/min), tHR (theoretical maximal heart rate, b/min) $\%HR_{max}$ (percent of the maximum heart rate, %) EEt (minute energy consumption during effort, kcal/min), CHO (carbohydrate metabolism, %) and Fat (fat metabolism, %) were all included as functional parameters.

As a result of T1 (VO_2max), 5 cardiovascular training zones (Zones 1-5) were created by using the percentage of the determined maximal heart rate values. Training Zone 1 (55-75% of HR_{max}) and Zone 2 (75-85%) were used as aerobic exercise zones. Zone 3 (85-90%) represented a mixed exercise zone, while Zones 4 (90-95%) and 5 (95-100%) were implemented as anaerobic exercise zones (Seiler & Tonnessen, 2006).

- *Training analysis*

Following the VO_2max testing, a training program was implemented between day 2 and day 23, including 14 roller skiing sessions, 10 cycling, 11 trail running and 4 Nordic walking sessions. During the 31 training sessions, the athletes covered a median distance of 950.6 km in 3.507 minutes. Of all the trainings, 2 sessions per day were conducted on 12 different days, while 1 single training session per day was conducted on 7 different days. During 3 of the 23 training days, no training sessions were scheduled.

Training analysis (days 2-23) was documented in a Microsoft Excel database. Using Polar V400 and Polar H7 Bluetooth CardioFrequency Meter, the following parameters were monitored: effort time (minutes), distance (km), heart rate (HR, b/min), positive altitude (+meters) and negative altitude difference level (-m), along with the HR value in the following 5 exercise zones (55-100% of HR_{max}), in order to confirm the training objective.

- *Classic roller skiing test*

During the 24th day, a specific roller skiing test (T2) was performed. No training sessions were scheduled 48 hours before the specific test (days 22 and 23) in order to minimize the impact of fatigue on the obtained results. The athletes' food intake was standardized 48 hours before the test at a similar quantitative and qualitative value. Macronutrient consumption was set at 8.6 g/kg carbohydrates, 1.8 g/kg protein and 1.2 g/kg fat 24 hours before the test. No medication was administered prior to effort.

The test involved competing in a classic roller skiing event over a 5 kilometer track (385 meters positive altitude difference; no negative altitude difference level). The start of the effort was programmed at 30 second intervals. The time was recorded digitally (hh:mm:ss) by recording the time needed to perform the distance, from the start (point *a*) to the finish (point *b*) of the track. Using the Polar V400 and Polar H7 Bluetooth heart rate monitor, the following parameters were measured: total exercise time (minutes), distance (km), speed (km/h), altitude difference gain, heart rate (HR, b/min), and the HR value in the following effort zones: Z1-Z5 (55-100% of HR_{max}).

d) Statistical processing

*Statis*tical analysis was performed using the GraphPad Prism 5.0 software. Standard deviation (SD), coefficient of variation (CV%), and median values were used in the descriptive analysis. The Normality D`Agostino & Pearson test was applied, while several correlations between two different or similar parameters, analyzed during T1-T2, were obtained by applying the Spearman test and one sample *t* test. A *p* value of <0.05 value was considered statistically significant, with the confidence interval (CI) assigned to a standard value of 95%.

Results

Maximal exercise testing analysis (VO_2max)

The maximum volume of oxygen was measured at 68.12 ml/min/kg. Following the test, VT_1 was measured at 152.5 b/min, while VT_2 reached 189 b/min. During the test, the median heart rate reached 97.97% of the theoretical HR_{max}. Due to an increased heart rate percentage, VO_2/HR ratio was stated at 22.48 ml/b/min. VE was monitored at a median value of 90.2 l/min, with a determined VT of 2.13 L/min and 37.42 b/min respiratory frequency. VE/VO_2 was measured at a median value of 25.01, while VE/VCO2 reached 27.09.

During the test, the energy expenditure was estimated at a median value of 17.54 kcal/min. Based on the RQ evolution, 32.17% of the energy use was attributed to fat metabolism, while 67.82% was attributed to carbohydrate metabolism. Further on, the end-tidal oxygen tension was measured at 104.2 mmHg, while end-tidal carbon dioxide tension reached 40.97 mmHg during the VO_2max test.

Training analysis

In training, the roller skiing sessions were conducted in 1128 minutes over 366.8 kilometers, at a median heart rate of 63.10% of HR_{max}. The cycling sessions were conducted over 428.5 km, unlike roller skiing which reached 366.8 km distance (p=0.07). During the cycling training sessions, the athletes reached a median training time of 1168 minutes (p>0.05), performed at 55.89% of HR_{max}, compared to the roller skiing training, performed at 63.10% of HR_{max} (p=0.01). The trail running sessions were programmed in 693.3 minutes of exercise, over 127.5 km distance. The median heart rate percentage reached 65.7% of HR_{max}, representing the most elevated HR%, compared to cycling (p=0.01) and roller skiing values (p=0.01). Nordic walking sessions were performed over 406.8 minutes, reaching only 44.05 km distance. The median HR during the Nordic walking sessions was measured at 60.14% of HR_{max}, being lower than the running HR% (p=0.01), but higher than the cycling HR% (p=0.08).

As part of the training report, no more than 1.293,38 minutes of exercise (36.88%) were conducted in training zone 1, while 1.157,66 minutes (33.01%) were completed in training zone 2. Further on, during training, 688.42 min (19.63%) were conducted in exercise zone 3, with a reduction for training zone 4 to a median time of 138.17 min (3.94%), while 137.82 min (3.93%) of the total training time were conducted in training zone 5. During general analysis, aerobic training was performed over 2.451,04 min, representing as much as 69.89% of the entire activity that was conducted between the first tests (T1) (day 1 of 24) and the second tests (T2) (day 24 of 24).

Classic roller skiing test analysis

T2 evolution had a median run time of 21.36 minutes over a 5 km distance. The median speed was monitored at 13.40 km/h, while the maximum speed reached 22.80 km/h. Based on the test analysis, the median HR value, during T2, reached 92.8% of HR_{max}, being statistically different from the T1 median HR% value (p=0.03) (Fig. 2).

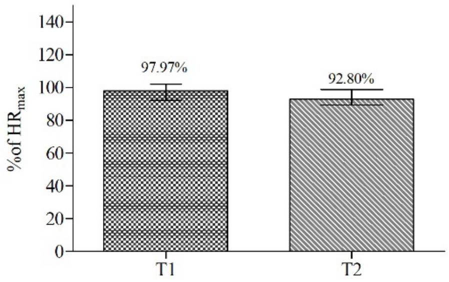

Fig. 2 – Differences in the HR_{max} value monitored during T1 and T2 (p=0.03), presented as median values+ range

As a result, 83.52% of the exercise was conducted between 95-100% of HR_{max}, representing the exercise zone 5, as shown in the descriptive data illustrated as median, minimum and maximum values, in Table I.

The race time was statistically related to HR evolution during the exercise (p = 0.01, r = -0.87, 95%CI = -0.96 to -0.59). Improved testing performances were related to an elevated speed (p = 0.01, r = 0.97, 95%CI = 0.91 to 0.99) and a reduced track time throughout conducting a constant effort, from point *a* to point *b,* at a value between 90-100% of HR_{max} (p = 0.01, r = -0.98, 95%CI = - 0.99 to -0.94). A lower T2 time, as against an improved T2 time, was related to a reduced HR range, stated between 85-90% of HR_{max} (p=0.01, r= - 0.85, 95%CI = -0.96 to -0.44).

Table I

Roller skiing testing (T2) descriptive analysis, illustrated as median, minimum and maximum value

Training related data	Median	Range	
		Minimum	Maximum
Distance, km	5	5	5
Time, min	21.36	20.40	23.75
Positive difference level, m	386	386	386
Speed, km/h	13.40	12.30	22.80
$\%HR_{max}$	92.80	89.30	98.85
Z5, %	83.52	14.66	99.85
Z4, %	8.79	0.09	76.06
Z3, %	3.78	0.01	9.22
Z2, %	0.39	0.01	3.14
Z1, %	0.02	0.01	0.33

An increased VT_1, during T1 analysis, was related to the athlete's maximal HR during T2 (p = 0.01, r = 0.84, 95%CI = 0.52 to 0.95). Withal, both VT_1 (0.03, r=0.60, 95%CI =0.05 to 0.87) and VT_2 values (p = 0.03, r = 0.60, 95%CI = 0.02 to 0.87) were significantly correlated with the median pace during T2. Over T1, the monitored VE values were

Table II

Training influence over the specific 5k roller skiing competition test

Proposed parameters				Statistical results			
General training (days 2-23)	Median value (range)	T2 performance parameters	Median value (range)	p	r	95% confidence interval	
						Upper	Lower
Training in Z1,%	36.88 (0 – 146.6)	Time, s	21.36 (20.5 – 23.7)	0.01	-0.90	-0.97	-0.67
		$\%HR_{max}$	92.80 (89.3 – 98.8)	0.01	0.99	0.98	0.99
		Average speed km/h	13.40 (12.3 – 15.1)	0.01	0.98	0.95	0.99
		Maximum speed km/h	22.80 (19.8 – 26.2)	0.01	0.98	0.93	0.99
Training in Z2,%	33.01 (0 – 48.334)	Time, s	21.36 (20.5 – 23.7)	0.96	-0.01	-0.58	0.56
		$\%HR_{max}$	92.80 (89.3 – 98.8)	0.12	-0.46	-0.81	0.15
		Average speed km/h	13.40 (12.3 – 15.1)	0.40	-0.26	-0.72	0.36
		Maximum speed km/h	22.80 (19.8 – 26.2)	0.26	-0.37	-0.76	0.28
Training in Z3,%	19.63 (0 – 22.93)	Time, s	21.36 (20.5 – 23.7)	0.05	0.56	-0.01	0.85
		$\%HR_{max}$	92.80 (89.3 – 98.8)	0.01	-0.87	-0.96	-0.60
		Average speed km/h	13.40 (12.3 – 15.1)	0.01	-0.80	-0.94	-0.42
		Maximum speed km/h	22.80 (19.8 – 26.2)	0.01	-0.87	-0.96	-0.60
Training in Z4,%	3.94 (0.86 – 17.55)	Time, s	21.36 (20.5 – 23.7)	0.01	0.94	0.80	0.98
		$\%HR_{max}$	92.80 (89.3 – 98.8)	0.01	-0.69	-0.90	-0.20
		Average speed km/h	13.40 (12.3 – 15.1)	0.01	-0.83	-0.95	-0.49
		Maximum speed km/h	22.80 (19.8 – 26.2)	0.01	-0.76	-0.93	-0.34
Training in Z5,%	3.93 (0 – 17.55)	Time, s	21.36 (20.5 – 23.7)	0.01	0.89	0.67	0.97
		$\%HR_{max}$	92.80 (89.3 – 98.8)	0.04	-0.58	-0.86	-0.02
		Average speed km/h	13.40 (12.3 – 15.1)	0.01	-0.74	-0.92	-0.29
		Maximum speed km/h	22.80 (19.8 – 26.2)	0.01	-0.66	-0.89	-0.14

significantly correlated with the oxygen volume (p=0.01) and the carbon dioxide excretion ratio (p=0.01). Therefore, a significant statistical relationship was established between the determined VE (p=0.03, r=0.62, 95%CI = 0.88 to 0.07), VO_2 (p=0.01), VCO_2 (p=0.01), during T1, and the individual's capacity to perform during T2 in exercise zone 5.

During T1, the $PetCO_2$ was significantly correlated with the VCO_2 determined value (p=0.01), relating an improved CO_2 removal rate. Unlike $PetCO_2$ effects on T2 performances, through $PetO_2$ analysis, no similar results were found (p≥0.05).

An increased training time (CV=15.79%) within the 23 day period was associated with an improved effort time during T2 (p=0.01). Based on the analysis, training in effort zones 3 (85-90% of HR_{max}) and 4 (90-95% of HR_{max}), unlike training in effort zones 1 and 2 (55-85% of HR_{max}), was associated with an impaired pace during T2. Improved performances, based on T1 analysis, were related to an increased pace (speed) and HR% during T2. However, this adaptation was monitored as a result of the general aerobic training, in association with short intensive activity, within the 23 day training period, as shown in Table II.

Discussion

During many recent studies, different testing protocols have been applied to provide additional data regarding the effort capacity (Losnegard & Hallén, 2014a).

The main training objective during a specific effort will offer important information in order to choose a medium-long term testing protocol. The main differences between different types of physical activities are related to the fact that each one involves different functional demands (Hébert-Losier et al., 2017). Applying the correct protocol will simulate event-specific physical demands under different conditions. In contrast to this hypothesis, we managed to conduct and obtain important data regarding a non-specific maximal test and its interpretation over a specific maximal activity.

Training impact on specific exercise performances

Through the obtained results, we can confirm that increased aerobic training, as opposed to general anaerobic effort, can induce an enhanced performance through an improved effort capacity. According to Stangier et al. (2016), conducting both running and cycling training sessions during a general training period, at 50-60% of HR_{max}, can generate a positive effect on the aerobic capacity.

In our study protocol, both cycling and running were included as training sessions, along with roller skiing and Nordic walking training. Of the programmed activity, roller skiing and trail running sessions represented both low intensity and high intensity training methods, while cycling and Nordic walking sessions were used only as aerobic training activities. Through our findings, we confirm that all of them, being part of the training program, had an important role in achieving the main objective. Yet, the results of Ateş & Çetin (2017) illustrate improvements during roller skiing training, unlike other training methods. In our study, an increased aerobic activity over the 23-day training cycle was significantly correlated with the athletes' ability to perform in exercise zone 5, generating an improved pace during T2 testing. As a result, we believe that high volume and moderate intensity training, combined with inappropriate recovery periods, can have an opposite effect on the athletes' capacity during high intensity activity, similarly to the outcomes of Seiler & Kjerland (2006).

T1 results were related to the actual T2 performances, contrary to the results of Losnegard & Hallén (2014b), who found similar improvements but during submaximal effort, as against maximal activity. However, we obtained important results regarding the cardiopulmonary evolution and the athletes' specific effort performances that can influence O_2 extraction as described by Boushel et al. (2014), during maximal activity.

VO_2max test as a performance predictor in specific exercise

The highest aerobic power is measured in cross-country skiing athletes, compared to any other sport. Both absolute (L/min) and relative aerobic power values (ml/min/kg) are very important in the activity outcome, as described by Holmberg (2015). Unlike the median values measured in our study, at 68.71 ml/min/kg, values up to 90 ml/min/kg can be measured in different training stages of elite cross country skiers, as seen in the paper of Sandbakk & Holmberg (2014).

From a practical point of view, the aerobic power will be proportional to the maximum volume of oxygen, as shown in our results through the aerobic power results. The method of analysis is of particular importance, as shown by Sandbakk et al. (2016). In the current paper, due to unavailable equipment, the VO_2max test was performed on a running treadmill, unlike the tests performed in other studies by using a specific roller skiing treadmill. Published papers regarding the comparison of the two testing methods presented differences in the determined VO_2max values (Vergès et al., 2006). Therefore, our results regarding cardiopulmonary evolution can be compared with the partial outcomes of the treadmill testing presented by Losnegard & Hallén (2014b). According to the results of Losnegard & Hallén (2014b), during a treadmill running test, the measured VO_2 value will be higher as opposed to the one recorded during specific cross-country roller skiing.

Both aerobic and anaerobic capacity defines the athletes' performance during specific or general effort. Based on our findings, $PetCO_2$ evolution over the T1 test was used as an important prediction factor for the CO_2 excretion rate. Unlike this outcome, Larsson et al. (2002) and Stöggl et al. (2017) did not illustrate a direct relationship between the athletes' performance and $PetCO_2$ evolution during laboratory tests. In our analysis, $PetCO_2$ and VE/VCO_2 evolution, during T1, was significantly correlated with the median pace during T2, unlike in the paper of Hébert-Losier K et al. (2017), which failed to link the laboratory test results with the specific exercise performances. An elevated ventilation was strongly related to a lower VT measurement and an increased VO_2 value, establishing a strong correlation with the median HR value during T2. However, an increased heart rate during T2 was related to both an improved effort zone 5 performance and an elevated pace during the effort. As a result, VT_1 measurement was related to an increased VE, which was associated with an important rise in VO_2 and a proper adapted $PetCO_2$, during T1, generating an important influence on the athletes' capacity during T2 maximal exercise. Yet, Verges et al. (2003) illustrated a similar hypothesis, but without any differences regarding lactate production during the two tests. The main differences regarding aerobic power were identified during the specific test as opposed to the indoor running test.

Conclusions

1. Through VO_2max testing, the cardiopulmonary non-specific analysis represents an important method used to analyze functional and individual performance.

2. The actual impact of training on a high intensity exercise evolution is related to aerobic training, during a medium period of time, which, in our analysis, was stated at a 65% aerobic exercise.

3. During T1, an increased aerobic activity was correlated with an improved pace and exercise time over T2. However, an increased VE value, along with VO_2 and VE/VO_2, generated an improved $PetCO_2$ ratio and athletes' performance, through an enhanced oxygen extraction, resulting in an improved T2 time, due to an increased aerobic power, stated during the non-specific testing.

4. Proper cardiopulmonary development, based on a well-established ratio between ventilation, oxygen volume, oxygen extraction and CO_2 removal rate, during a non-specific maximal test, related the athlete's capacity to perform over a high intensity specific exercise.

Conflicts of interest

The authors of this paper state that there are no conflicts of interest regarding the study methodology, results and conclusions drawn.

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