

Детерминанты кардиореспираторной выносливости у мужчин, увлекающихся катанием на беговых лыжах

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Целью исследования являлась оценка показателей физической активности мужчин, увлекающихся катанием на беговых лыжах, а также выявление предикторов, связанных с изменением переносимости нагрузки. В ходе работы использовался тредмил-тест. Для диагностики состава тела применялся метод биоимпедансного анализа. Было показано, что с уровнем максимального потребления кислорода коррелировали следующие показатели: процент жира в организме, скорость бега (максимальная) (км/ч), скорость бега (конечная) (км/ч), вентиляция (л/мин) и физиологические затраты на бег (мл/кг/км). Учет предикторов изменения переносимости физической нагрузки необходим в практике для разработки наиболее подходящего плана обучения катанию на беговых лыжах.

Ключевые слова: катание на беговых лыжах, любители, максимальное потребление кислорода, предикторы.

Конфликт интересов: не заявлен.

Финансирование. Исследование выполнено при финансовой поддержке со стороны Министерства науки и высшего образования (грант № 71/E-716/S2018), а также субсидии для поддержания исследовательской деятельности в 2018 году для Школы Гостиничного Бизнеса (группа университетов Вистула в Варшаве).

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Рукопись получена 21.08.2019

Рецензия получена 06.09.2019

Принята к публикации 13.09.2019



Для цитирования: Grzebisz N, Piejko L, Sulich A. Детерминанты кардиореспираторной выносливости у мужчин, увлекающихся катанием на беговых лыжах. *Российский кардиологический журнал*. 2019;24(12):109–113
doi:10.15829/1560-4071-2019-12-109-113



Determinants of cardiorespiratory fitness in amateur male cross-country skiers

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The aim of the study was to present the performance parameters, their assessment and their predictors in the group of amateur cross-country skiers at the beginning of the preparatory period. For this purpose, incremental exercise tests were carried out on the treadmill. Body composition measurement was performed using impedance analyzer. The main findings of the study were that the most correlated with VO_2 relative (max) were percentages of body fat, running speed (maximum) (km/h), running speed (final) (km/h), ventilation (L/min) and physiological cost of running (ml/kg/km). The appointment of the predictors can be an effective tool to assess the efficiency of this group and prepare a proper training plan for them.

Key words: cross country skiers, amateur, $\text{VO}_{2\text{max}}$, predictors.

Conflicts of Interest: nothing to declare.

Funding. The study received financial support by the Ministry of Science and Higher Education (grant No. 71 / E-716 / S2018) the entity subsidy to maintain the research potential (base subsidy) in 2018 for Vistula School of Hospitality, Vistula Group of Universities in Warsaw.

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Received: 21.08.2019 **Revision Received:** 06.09.2019 **Accepted:** 13.09.2019

For citation: Grzebisz N, Piejko L, Sulich A. Determinants of cardiorespiratory fitness in amateur male cross-country skiers. *Russian Journal of Cardiology*. 2019;24(12):109–113. (In Russ.)
doi:10.15829/1560-4071-2019-12-109-113

Sports training is a long-term process. It is focused on achieving the maximum capacity of the body. This applies to all aspects in the mental and physical sphere of a sportsman. They are caused by numerous adaptation mechanisms. They occur in the cardiovascular, muscular, nervous, hormonal and an immune system. The weight and composition of the body are also important. They are most visible in athletes of endurance disciplines (for

example: cross-country skiing, triathlon, cycling etc.). Monitoring and evaluation of physiological changes is essential in the training process, also in nonprofessional athletes.

The aim of the study was to determine and evaluate the baseline of cardiovascular capacity in amateur athletes who have started in long distance races. In addition, predictors for maximum oxygen uptake were determined.

Characteristics of the study group

Variable	Arithmetic average (N=16) means±SD (difference Δ — delta)
Age (years)	38.69±7.95 (28.00-56.00)
Body height (cm)	181.44±6.53 (169.00-197.00)
Body mass (kg)	78.52±6.18 (68.10-91.50)
Fat mass (kg)	12.22±2.53 (7.90-16.00)
Fat mass (%)	15.51±2.59 (10.00-19.30)
BMI (kg/m ²)	23.84±1.35 (21.00-25.70)

Note: all data are presented as means ± standard deviation and the difference (Δ — delta).

Abbreviations: BMI — Body Mass Index, N — number of patients, SD — Standard deviation.

Table 1

the cross-country skiers after the recovery period, at the beginning of the macrocycle, and their predictors.

Material and methods

The study was conducted in accordance with the guidelines of Good Clinical Practice and the Helsinki Declaration. The test report was approved by the Bioethics Committee. All participants submitted a written consent for research. The research group consisted of 16 well-trained amateur skiers. The competitors worked professionally in a big city and could spend up to 90 minutes daily for physical training.

The research was carried out at the end of the recovery period in May. The goal was to determine and evaluate the parameters of circulatory-respiratory fitness and predictors of maximum oxygen uptake. The criteria for inclusion in the study were: consent to participate in the study, possession of current medical approval, completion of at least three long distance races in the last season. Exclusion criteria were: lack of consent for participation in the study, poor health, lack of medical consent.

Body weight and the weight were measured on Tanita Body Composition Analyzer BODY IN MC-980 MA consisting of an 8-point touch electrode system. The test was carried out just before the incremental exercise tests began. The following were determined: body weight, water content, minerals, vitamins, fat content in the body (% and kg) and slim mass muscle (muscle mass in % and kg), WHR (waist to hip ratio) and BMI (body mass index). Body weight and body composition are important in endurance sports. They have a significant impact on the level of maximum oxygen uptake, which is the best measure of the ability of endurance athletes (especially content of adipose tissue and body muscle). Changes toward lower values of body fat are characteristic of a healthy influence of endurance training. Detailed data characteristics of the study group are shown in Table 1.

Incremental exercise test. To assess the aerobic capacity expressed by the level of maximum oxygen uptake ($\text{VO}_{2\text{max}}$) an incremental exercise test was used with gradually increasing intensity. This test was performed on a treadmill using HP Cosmos CPET equipment and Cosmed Quark/k4B2. The test started at speed of 6 km/h and 0% treadmill inclination. Then every 3 minutes, the speed was increased by 1 km/h, and the inclination by 1%. The test was continued until the subjective feeling of exhaustion by the competitor (to refuse). The frequency of heart contractions at rest and during exercise was recorded using the Garmin ANT+ heart rate monitor. The paper presents below the maximum results of the test.

Statistics. Variables were analyzed using basic descriptive statistics: number of persons (N), arithmetic mean, median, minimum (Min), maximum (Max) and standard deviation (SD). The Pearson correlation coefficients were used, whose values — in the case of

Table 2
The Pearson correlation coefficients used in the case of statistical significance

Coefficient (r)	Interpretation
$0.0 \leq r \leq 0.2$	no correlation
$0.2 < r \leq 0.4$	Weak correlation
$0.4 < r \leq 0.7$	Average correlation
$0.7 < r \leq 0.9$	Strong correlation
$0.9 < r \leq 1.0$	Very strong correlation

It is an indicator of maximum exercise capacity. Systematic physical activity can protect such people against an early heart attack and civilization diseases such as obesity and overweight with their consequences. On the other hand, long distance races are becoming more and more popular among amateurs. This is easily seen in the steadily increasing number of participants in such competitions.

Cross-country skiing is an endurance effort that involves almost all muscle groups and requires sustained endurance strength training preparations. Adjusting the right training plan is therefore the key to achieve the goals in the base-building period. It is also the main factor that can protect against excessive strain on the body by physical effort. The level of efficiency of highly qualified athletes is well known and described in the literature, but there is still lack of information about these parameters at amateur athletes. Due to the specificity of sport and physical effort, as well as trends in society, the issues raised are extremely important. Setting predictors for maximum oxygen uptake can give important data for trainers, nutritionists and physicians cooperating with such persons. This paper takes into consideration those issues and presents the results of the ergospirometry test and the evaluation of the results of

Table 3

Descriptive statistics for maximum capacity
of the study group

Variable	Arithmetic average (N=16) means±SD (difference Δ — delta)
Test time (sec)	1550.62±141/40 (1300.00-1740.00)
Maximum respiratory rate (breaths/minute)	58.94±12.30 (46.00-91.00)
The physiological cost of the effort (ml/kg/km)	227.81±18.87 (205.00-275.00)
Running speed (final) (km/h)	13.75±1.06 (12.00-15.00)
Maximum speed of running (km/h)	13.86±0.78 (12.30-15.10)
VO ₂ max (absolute) (L/min)	3.83±0.51 (2.80-4.50)
VO ₂ max (relative) (ml/kg/min)	48.37±5.06 (38.54-55.81)
HRmax (bpm)	183.38±9.66 (156.00-195.00)
Ventilation max (L/min)	144.32±23.08 (100.20-184.00)

Note: all data are presented as means±standard deviation and the difference (Δ — delta).

Abbreviations: HRmax — maximum heart rate, VO₂ max — maximal oxygen uptake, n — the number of patients, SD — standard deviation.

statistical significance — can be interpreted as follows in Table 2. The value of 0.05 was assumed as the significance level (denoted by * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

The calculations were made in the statistical software (ver. 3.6.0).

Results

The Table 3 shows results of descriptive statistics for maximum capacity during the treadmill exercise test in the group of athletes.

Correlations for independent variables. The VO₂ variable relative (max) had significant correlations with 7 variables. Most of these correlations were moderately strong or strong, and positive. The results are shown in Table 4.

Discussion

The main findings of the study were that the most correlated with VO₂ relative (max) were percentages of body fat, running speed (maximum) (km/h), running speed (final) (km/h), ventilation (L/min) and physiological cost of running (ml/kg/km).

The studies of body composition showed that the average value of this parameter was 78.52 kg and the adipose tissue content was at the level of 15.5% (12 kg). The level of body fat was at medium level. The desirable range of adipose tissue content ranges for amateurs from

Table 4

P-values and correlations for the VO₂
variable relative (max) of the athletes

Variables	P-value	Correlation
% Fat mass	0.013	-0.605
Time test (sec)	0.008	0.639
Maximum speed of running (km/h)	0.018	0.583
Running speed (final) (km/h)	0.018	0.581
VO ₂ max (absolute) (L/min)	0.000	0.842
Ventilation max (L/min)	0.004	0.677
The physiological cost of the effort (ml/kg/km)	0.020	0.575

11.0–14.00% (rated as good) to 20.0% (rated as acceptable). Elite athletes have significantly lower score. In previous research [1] we noted lower fat mass 13.85%. A reduction in body fat in the body by about 3–5% could improve the efficiency of movement and increase VO₂ max. Too high body weight has an adverse effect on the musculoskeletal system. This increases the possibility of the occurrence of overload injuries. By reducing body mass and accordingly by reducing body fat, the level of oxygen intake per kilogram of body weight increases. This translates into better exercise capacity. The decrease of this parameters are desirable. This was also confirmed by the results of correlations, in which fat tissue was the strongest variable for VO₂ max.

Cross-country (XC) skiing is one of the most demanding sport disciplines. It involves protracted competitions on varying terrain employing a variety of skiing techniques that require whole body work to different extent. Sport-specific peak aerobic power (VO₂ peak) is one of the main determinants of performance in sprint and distance cross-country skiing [2]. Several studies [3, 4] showed that world-class skiers are among the endurance athletes with the highest VO₂ max. It has been associated in both sex with maximal values above 70 and 80 ml/kg/min or 4.0 and 6.0 l/min.

Other scientists [2] monitored physiological differences between sprint and distance-specialized cross-country skiers. In this research the elite male sprint skiers showed different anthropometric and physiological qualities than the distance skiers, with these differences being directly related to body mass (with sprinters weighting more than distance skiers). The elite distance skiers had higher VO₂ max than our amateur (83.0±3.2 vs 48.37±5.06) and they were lighter (71.8±7.2 vs 78.52±6.18 kg) and shorter (178±7 cm 181.44±6.53). They BMI was smaller than in amateur (22.5±1.3 kg/m² vs 23.84±1.35). But in the older groups of long-distance cross-country skier the results were lower than in other elite athletes, but still higher than in our research (VO₂ max: 64±5 vs our result 48.37±5.06) [5]. In other studies [6] elite cross-country skiers were younger (aged 25±4 years) and they had a higher VO₂ max (65±4 ml/kg/min). The highest values were recorded at

one Norwegian skier (7.48 liters per minute, which was 94 ml per kilogram of body weight [7]), but they were similar to results of best professional marathon runners and cyclists. We should emphasize that the differences are noted between specialized long-distance versus all-round skiers. The first group was characterized by lower VO_2max , but they had a reduced oxygen cost [8].

The age in our group (38.69 ± 7.95) was significantly higher than among the best long-distance skiers. According to Knechtle and Nikolaidis [9] the age of peak performance of cross-country skiers competing in long distance races was much lower and closer to the peak of aerobic capacity than what was found in previous studies in marathon road runners. In our study (VO_2max) it was 48.37 ml/kg/min and 3.83 l/min. These results were lower than those reported among professionals in all disciplines and specializations, but higher than those found in the population.

The previous results showed that exercising at very vigorous intensity may be beneficial for oxygen uptake [10]. In person who trained systematically (but not as a professional athlete) the VO_2max level was 47.5 ml/kg/min. In group without impact of exercise VO_2max was lower (40.1 ml/kg/min). In our research the average VO_2max was similar to people who reported 75-149 min activity per week.

WHO guidelines on pro-health activities indicate the desired level of VO_2max as 35 ml/kg/min. In this case, the athlete substantially complies with these guidelines. The high level of maximum oxygen uptake supports the circulatory-respiratory system, quality of life and health protection. This is particularly important in older people who have sarcopenia and the problem of overweight and obesity. It is estimated that every year the level of maximum oxygen uptake decreases about 0.5-0.6 ml/kg/min. In active people that decrease is smaller. Parameters measured in the study were higher, which may affect the state of health. It is worth emphasizing the three-year risk for mortality based on achieved VO_2max . Patients who achieve a VO_2max greater than 17 ml/kg/min have an associated three-year risk of about 20%, significantly lower than in patients who achieve a peak value less than 14 ml/kg/min.

In the group VO_2max level was significantly higher than in population. This could indicate the health-promoting effect of such a lifestyle. In recent decades, methods of cardiac rehabilitation have been widely used in patients after acute myocardial infarction, coronary syndrome and cardiac operations [11]. It is well known that short-term high-intensity interval training (HIIT) to moderate-intensity continuous training (MICT) have impact on improving cardiorespiratory fitness, markers of inflammation, and glucose control in previously inactive adults with elevated risk of developing type 2 diabetes [12]. That type of physical activity could be added to the program of patients' pre-rehabilitation programs before

on-pump coronary artery bypass grafting (CABG) [13]. This result shows that cross country skiing could be successful physical activity in prevention this disease.

Maximum ventilation (VE), which is one of the indicators determining the efficiency of the respiratory system, was at the level of 144.32 l/min. These are mediocre values. The reason for this may be poor biomechanics of breathing, respiratory disease or too much body weight. The maximum rate of heart contractions (HRmax) was 183.38 bpm. This value is genetically determined. At this age, there are no statistically significant changes as a result of physical training. Prevention of cardiovascular disease has to be integrated into primary health care.

Predictors

The main findings of the study were that the most correlated with VO_2 relative (max) were percentages of body fat, running speed (maximum) (km/h), running speed (final) (km/h), ventilation (L/min) and physiological cost of running (ml/kg/km). To this moment no VO_2max predictors in amateur sport have been determined. This makes their reference and assessment difficult. Nevertheless, this information suggests that to improve the athletes' level of sports, body fat should be reduced. This will significantly affect the cardiovascular capacity and increase the remaining parameters. This can be achieved mainly thanks to the use of aerobic effort and an appropriate, balanced diet and supplementation. In addition, these behaviors will affect the improvement and protection of health. This study took into account the results of body composition and maximum exercise parameters. In the future, they should be extended, for example, by analysis of morphology, acidity and performance parameters at the anaerobic threshold.

Conclusion

The results of the study present the cardiovascular capacity of amateur cross-country skiers and its predictors. According to our knowledge, this paper is the first one in the literature that presents the assessment of such a group. Previously, only a case studies were presented.

In the literature, the attention is paid to improve mental tolerance of exercises under the influence of physical training, but only in professional athletes. Evaluation of cardiopulmonary resuscitation devices in middle-aged persons is the starting point in the preparation of competitors for repeated participation in long-distance races in the winter season and protection against civilization diseases. The use of systematic physical training results in lower adipose tissue content and a higher level of maximum oxygen uptake as compared to the recommended for the population. It also has a significant impact on increasing the efficiency of the cardiovascular and respiratory system and protection of the heart against early infarcts, as well as

obesity and overweight and their consequences. However, the measured parameters were significantly lower than in professional athletes. The most correlated with VO_2 relative (max) were: % body fat, running speed (maximum) (km/h), running speed (final) (km/h), ventilation (L/min) and physiological cost of running (ml/kg/km).

Conflicts of Interest: nothing to declare.

Funding. The study received financial support by the Ministry of Science and Higher Education (grant No. 71 / E-716 / S2018) the entity subsidy to maintain the research potential (base subsidy) in 2018 for Vistula School of Hospitality, Vistula Group of Universities in Warsaw.

Литература/References

1. Grzebisz N, Piejko L. The impact of endurance exercise on the cardiovascular capacity of a male amateur cross country skier. Pilot study. *World Scientific News*. 2018;110:72-83.
2. Losnegard T, Hallen J. Physiological differences between sprint- and distance-specialized cross-country skiers. *International Journal of Sports Physiology and Performance*. 2014;9(1):25-31. doi:10.1123/ijspp.2013-0066. Epub 2013 Oct 23.
3. Sandbakk Ø, Losnegard T, Skattebo Ø, et al. Analysis of classical time-trial performance and technique-specific physiological determinants in elite female cross-country skiers. *Frontiers in Physiology*. 2016;7:326. doi:10.3389/fphys.2016.00326. eCollection 2016.
4. Tønnessen E, Sylta O, Haugen TA et al. The road to gold: training and peaking characteristics in the year prior to a gold medal endurance performance. *PLoS One*. 2014;9(7):e101796. doi:10.1371/journal.pone.0101796. eCollection 2014.
5. Børve J, Jevne SN, Rud B et al. Upper-Body Muscular Endurance Training Improves Performance Following 50 min of Double Poling in Well-Trained Cross-Country Skiers. *Frontiers in Physiology*. 2017;2:8:690. doi:10.3389/fphys.2017.00690. eCollection 2017.
6. Gejl KD, Ørtenblad N, Andersson E, et al. Local depletion of glycogen with supramaximal exercise in human skeletal muscle fibres. *Journal of Physiology*. 2017;595:2809-21. doi:10.1113/JP273109. Epub 2016 Nov 8.
7. Sandbakk O, Losnegard T, Skattebo O, et al. Analysis of Classical Time-Trial Performance and Technique-Specific Physiological Determinants in Elite Female Cross-Country Skiers. *Front Physiol*. 2016 Aug 3;7:326. doi:10.3389/fphys.2016.00326. eCollection 2016.
8. Skattebo O, Losnegard T, Stadheim HK. Double poling physiology and kinematics of elite cross-country skiers: specialized long-distance versus all-round skiers. *Int J Sports Physiol Perform*. 2019 Aug 26;1190-1199. doi: 10.1123/ijspp.2018-0471. [Epub ahead of print].
9. Knechtle B, Nikolaidis PT. The Age of Peak Marathon Performance in Cross-Country Skiing-The "Engadin Ski Marathon". *J Strength Cond Res*. 2018 Apr;32(4):1131-1136. doi:10.1519/JSC.0000000000001931.
10. Nes BM, Janszky I, Aspenes ST, et al. Exercise patterns and peak oxygen uptake in a healthy population: the HUNT study. *Med Sci Sports Exerc*. 2012 Oct;44(10):1881-9.
11. Aronov DM. Possible associations between recovery aerobic training and increasing the length of telomeres. *Russian Journal of Cardiology*. 2019;24(3):82-9.
12. Robinson E, Durrer C, Simtchouk S et al. Short-term high-intensity interval and moderate-intensity continuous training reduce leukocyte TLR4 in inactive adults at elevated risk of type 2 diabetes. *J Appl Physiol* (1985). 2015 Sep 1;119(5):508-16. doi: 10.1152/japplphysiol.00334.2015. Epub 2015 Jul 2.
13. Argunova YuA, Korotkevich AA, Pomeshkina SA, et al. Efficacy of physical trainings as cardioprotection method for coronary bypass surgery. *Russian Journal of Cardiology*. 2018;23(6):159-65. (In Russ.) Аргунова Ю.А., Короткевич А.А., Помешкина С.А., и др. Эффективность физических тренировок как метода кардиопротекции у пациентов перед коронарным шунтированием. *Российский кардиологический журнал*. 2018;(6):159-65. doi:10.15829/1560-4071-2018-6-159-165.