

MAXIMAL OXYGEN UPTAKE IN ESTONIAN YOUNG CROSS-COUNTRY SKIERS: A LONGITUDINAL STUDY

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Summary

Longitudinal studies have shown that VO_{2max} increases the most as the outcome of training in the age between 15-25 (Rusko, 2003). Meanwhile, it is not clear how much this increase is connected to training or other development values. The aim of the present study was to analyze maximal oxygen uptake longitudinally among 15-19 year old cross-country skiers and its relations with training characteristics. Methods: determination of anthropometrical data (height, weight, BMI) and aerobic capacity (VO_{2max}) in the age period from 15 to 19 years during 5 years in 58 skiers (41 males and 17 females). Results: The dynamics of relative VO_{2peak} (ml/kg/min) were not significant in comparison across all age groups in young male skiers. A significant positive trend of VO_{2peak} (l/min; ml/kg/min) was found in young female skiers in the 17-year-old age group compared with the previous age group. Significant relationship was detected between change of training volume and change of VO_{2peak} /kg (difference between the age of 15 and 19 years among male young skiers) ($r=0.475$, $p=0.002$). In conclusion, our study showed a moderate increase in VO_{2peak} during the age period of 15 to 19 years, whereas the increase was more pronounced in male than female skiers. VO_{2peak} of young cross-country skiers was associated with the age as well as with the training hours per week.

Keywords: aerobic capacity, VO_{2peak} , longitudinal study, cross-country skiing

Резюме

Проведённые многолетние исследования показали, что в результате тренировок наибольший подъём VO_{2max} наблюдается в возрастных группах от 15 до 25 лет (Rusko, 2003). Тем не менее, не ясно, в какой мере это увеличение связано с тренировочным процессом или другими показателями развития. Цель проведённых исследований заключалась в длительном анализе максимального потребления кислорода в возрастных группах от 15 до 19 лет и их связь с тренировочными характеристиками. Методика: измерение антропометрических данных (вес, рост, ИМТ) и определение аэробной работоспособности (VO_{2max}) в течении 5 лет в разных возрастных группах от 15 до 19 лет, проведённых среди группы из 58 лыжников (41 мужчина и 17 женщин).

В ежегодном наблюдении в динамике относительно показателей VO_{2peak} (л/мин; мл/кг/мин) не наблюдалось значительного расхождения данных среди всех возрастных групп молодых лыжников-мужчин. Значительная положительная тенденция показателей VO_{2peak} (л/мин; мл/кг/мин) была выявлена среди молодых лыжниц-женщин в возрасте 17 лет в сравнении с предыдущей возрастной группой. Наиболее значительная связь между изменениями объёма тренировок и VO_{2peak} /кг была выявлена в возрастных группах 15 и 19 лет среди молодых лыжников-мужчин ($r=0.475$, $p=0.002$).

Наши исследования показали умеренное увеличение VO_{2peak} в возрасте от 15 до 19 лет и в то же время увеличение было более выражено у лыжников-мужчин, чем у лыжниц-женщин. VO_{2peak} у молодых лыжников зависимо как от возраста, так и от количества тренировочных часов в неделю.

Ключевые слова: аэробная работоспособность, VO_{2peak} , многолетние исследования, лыжный спорт

Introduction

The maximal oxygen uptake (VO_{2max}) is recognized as one of the major quantitative traits in sports physiology and the most common parameter to demonstrate training effects. VO_{2max} is influenced by different environmental and genetic factors (Rankinen et al., 2000). On average, women's VO_{2max} values are 10% lower compared to men due to higher body fat mass and lower levels of haemoglobin (Pate et al., 1987; Durstine et al., 1987). During the growth and maturation period in 11-17 year-old humans, the increase of VO_{2peak} is affected primarily by body lean mass (Armstrong and Welsman, 2001).

Competitive cross-country skiing requires a high level VO_{2max} in addition to the other main characteristics of performance as skiing economy and maximal anaerobic skiing power. VO_{2max} level among world class skiers may increase up to 89-93 ml/min/kg (Rusko, 2003). It has been found that not all individuals achieve the maximum oxygen consumption plateau during maximal exertion. In this case it has been suggested to determine the highest level of oxygen uptake (VO_{2peak}) achieved in an exercise test to maximum exhaustion (Bassett and Howley, 2000; Armstrong and Welsman, 2001).

The aim of the present study was to analyze maximal oxygen uptake longitudinally among 15-19 year old cross-country skiers and its relations with training characteristics.

Material and methods

Participants of the present study were young cross-country and biathlon skiers (hereafter young skiers). The total number of subjects was 58 (41 males and 17 females). 52% of young skiers were current or former junior Estonian national team members. All study participants had five consecutive pre-participation health evaluations (PHE) from the age period of 15 to 19 years at Tartu University Hospital during the period 2002-2013. Study inclusion criteria for young skiers were regular specific cross-country skiing training during the observed age period and the PHE had to include an exercise test on treadmill determining the maximal oxygen uptake peak (VO_{2peak}). The study protocol was approved by the Research Ethics Committee of University of Tartu (protocol no. 196/M-30, and no. 207/M-9).

Personal history and training characteristics were obtained by using an internationally accepted questionnaire (Wappers, 2005). Subjects' height (cm) was measured using the metal anthropometer (± 0.1 cm) and body mass (kg) was determined by using

clinical scales (± 0.05 kg), body mass index (BMI) was calculated.

All incremental continuous exercise tests were performed on the treadmill (Telineyhtymä, Kotka, Finland). A standardized stress test protocol for cross-country skiers was used increasing treadmill inclination and speed. The duration of each load step was 3 minutes. All tests were performed to volitional exhaustion to obtain the parameters of maximal aerobic endurance. VO_{2peak} (absolute, l/min and relative, ml/kg/min) was determined by the direct breath-by-breath method using a gas analyzer *Oxycon Pro* version 5.2, Hoechberg, Germany. In addition, duration of the exercise test (min) was recorded. During the exercise test, heart rate was recorded by a sport-tester (*Polar Electro*, Finland). Gas analysis data were automatically calculated for every 30 sec period. VO_{2peak} was considered as the highest VO_2 rate achieved within 30 seconds at the end of the exercise test. The criteria for maximal exercise test were the following: (1) respiratory exchange ratio (RER) equalled at least 1.1; (2) $HR_{max} > 90\%$ of the age-predicted maximum calculated according to the formula $220 - \text{age}$ (Davis, 2006).

The change of VO_{2peak} (ΔVO_{2peak} , ml/kg/min) was obtained by calculating the differences of VO_{2peak} between the age groups of 15 and 19 years in young female and male skiers. Change of exercise test duration and the training volume per week were calculated similarly. In addition, dynamics of VO_{2peak} duration of exercise test and training volume were observed in each age group separately compared with the previous age group.

Statistical analysis was performed with the Statistical Package for Social Sciences (SPSS version 20.0 for WINDOWS). Descriptive data are presented as means (x) and standard deviations (SD). The dynamics of VO_{2peak} (ml/kg/min) and the duration of the exercise test (min) as change between five time-points were analyzed with repeated analysis of variance. The Pearson's correlation coefficient (r) was applied to determine the relationships between variables. *P* values of ≤ 0.05 were set as statistically significant.

Results

Anthropometrical and physical performance characteristics of young skiers by age and sex are presented in table. An increase in anthropometrical parameters among male skiers was significant in age groups 16, 17, 18 and 19 as compared with previous age groups. Among young female skiers, a significant increase in the same characteristics was found only in the 16-year-old and 17-year-old age group ($p \leq 0.01$, ≤ 0.001 accordingly) compared with the previous age

group. There were no statistically significant changes in the dynamics of mean BMI in different male and female age groups. Among young male skiers, a remarkable increase of the training volume (hours/week) was observed at the age of 16 years. In female skiers, no significant changes in the dynamics in training hours per week were found up to 18 years, whereas a significant increase was observed at the age of 19 ($p < 0.05$).

A significant improvement in the duration of the standardized exercise test performance (min) was detected in 16 and 17 years age groups among young male skiers and in young female skiers of 18 years in comparison with the previous age group. The dynamics of relative VO_{2peak} (ml/kg/min) were not significant in comparison across all age groups in young male skiers. However, we found a significant positive trend of VO_{2peak} (l/min) as well as VO_{2peak} (ml/kg/min) in young female skiers in the 17-year-old age group compared with the previous age group. The correlation analysis showed a statistically significant relationship between the change of training volume and the change VO_{2peak} (ml/kg/min) among young male skiers ($r=0.475, p=0.002$), but there was no significant relationship between these variables among female skiers ($r=0.331; p>0.05$).

Characteristics of young skiers by age and sex groups

| Age group (years) | 15 years | | 16 years | | 17 years | | 18 years | | 19 years | |
|--------------------------|-----------|-----------|--------------|--------------|--------------|-----------|-------------|------------|-------------|-----------|
| | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| Weight (kg) | 63.2±8.0 | 58.4±8.6 | 67.2±8.4*** | 60.2±6.8** | 69.7±7.8*** | 60.6±5.2* | 71.4±7.6*** | 62.3±4.4 | 72.5±8.2*** | 61.8±5.0 |
| Height (cm) | 176.8±5.5 | 167.1±4.2 | 179.6±5.8*** | 169.5±4.3*** | 180.9±5.6*** | 168.5±3.8 | 181.8±5.5** | 170.6±4.2 | 181.6±6.3 | 169.1±3.7 |
| BMI (kg/m ²) | 20.2±1.9 | 20.8±2.3 | 20.8±2.0 | 21.0±1.9 | 21.3±1.8 | 21.3±1.6 | 21.5±1.6 | 21.4±1.5 | 21.9±1.6 | 21.6±1.3 |
| Training volume (h/week) | 8.5±2.5 | 7.0±1.4 | 9.9±2.7** | 7.6±2.4 | 11.3±2.9 | 9.3±2.1 | 12.4±2.9 | 10.9±2.9 | 13.4±2.9 | 13.2±3.1* |
| ET duration (min) | 24.6±5.1 | 20.5±3.4 | 27.0±2.2* | 21.1±2.8 | 27.9±2.0* | 21.9±2.4 | 28.3±2.2 | 23.4±1.7** | 29.3±1.6 | 24.6±2.6 |
| VO_{2peak} (l/min) | 4.0±0.6 | 3.0±0.3 | 4.4±0.5*** | 3.1±0.1 | 4.7±0.6** | 3.4±0.3** | 4.8±0.7 | 3.4±0.3 | 5.0±0.5* | 3.5±0.4 |
| VO_{2peak} (ml/kg/min) | 64.1±6.1 | 53.9±5.9 | 66.1±4.7 | 53.0±5.2 | 67.0±4.5 | 55.4±5.5* | 67.6±5.7 | 54.9±5.0 | 68.1±5.0 | 57.1±5.2 |

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ compared to the previous age group; ET – exercise test.

Discussion

Competitive cross-country skiing belongs to the group of one of the most demanding sports events. In the classification of sports activities by Mitchell et al. (2005), which is based on the type and intensity of exercise performed, cross-country skiing is characterized as a sport with high dynamic and low to moderate static (depending on technique of skiing) capacities. Regardless of very different length of race distances – from sprint distances 1.5 km up to 50 km – all distances require high endurance performance (Stöggl et al., 2010; Rusko et al., 2003).

Several longitudinal studies among skiers have referred to VO_{2max} increase with age and training during the 15-20-year-old period. It has been estimated that the annual increase in VO_{2max} amounts to 1-3 ml/kg/min/year (Rusko et al., 1992; Rusko, 2003), which is in accordance with our results of young male skiers. The ability to tolerate a high percentage of VO_{2max} for a long term and to move efficiently are important factors for achieving better results (Lucia et al., 2008). We observed the significant correlation between Δ training volume and ΔVO_{2peak} (ml/kg/min), i.e. increase of training hours related positively to the dynamics of VO_{2peak} (ml/kg/min). Armstrong et al. (2011) concluded that young athletes can improve their VO_{2peak} through training, but the association between current habitual physical activity and aerobic fitness needs to be proven.

Conclusion

Our study showed a moderate increase in VO_{2peak} during the age period of 15 to 19 years, whereas the increase was more pronounced in male than female skiers. VO_{2peak} of young cross-country skiers was associated with the age as well as with the training hours per week.

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