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METABOLIC EFFECT OF STRENGTH ENDURANCE EXERCISE COMPLEX IN YOUNG CROSS-COUNTRY SKIERS

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Abstract. The aims of this study were to: 1) evaluate the metabolic changes of strength endurance exercises complex in young male cross-country skiers using heart rate (HR) and blood lactate (BLA) concentration indices; and 2) compare these changes with those occurring in the organism when performing a running load at the level of individual anaerobic threshold. Ten young skiers (17.2±2.2 yrs; 174.7±8.6 cm; 62.3±8.7 kg) were studied in preparatory period (May). A complex of 12 strength endurance exercises with moderate intensity and 1500 m running bout on indoor track with individually controlled HR of 170 – 180 beats·minute^{-1} were performed. HR was measured continuously with Polar Vantage NV Sporttester (Finland). BLA concentration was analysed immediately after 6th, 10th and 12th exercise and after 1500 m run and at the fifth recovery min after the strength exercises and running. A ranking was used for the evaluation of special performance. Study revealed that the metabolic reactions to the complex of strength exercises and running at the level of anaerobic threshold were very different, as shown by a quite similar mean HR after both exercises (168 and 170 beats/min, respectively) and different BLA values (5.90±2.70 and 2.70±0.75 mmol·l^{-1}, respectively). Correlation analysis revealed that lower ranking order significantly correlated with higher HR after different strength exercises (r=0.62-0.80) and with BLA concentration after the 10th and 12th exercises and with 5th minute of recovery (r=0.62-0.77). Our results suggest that using HR and BLA concentration indices after the standard strength exercise complex gives us valuable information about adaptational and metabolic changes in skiers and helps the guidance of training process. HR underestimates the muscle's metabolic state and excessive strength exercise complex intensity can be the outcome.

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Key words: Strength exercises complex - Heart rate - Blood lactate - Metabolic effect - Training guidance

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Introduction

Modern cross-country training is based on high volumes of endurance training during the preparatory period, adding speed training in the precompetition period, and engages in high intensity intervals before the most important competitions [7,19,20]. It is shown that many athletes seem to reach performance plateaus concurrent with plateaus in VO_2max, anaerobic threshold and other physiological parameters [12,17]. Major changes in training stimuli may be necessary in order to further improve the performance. Rusko [18] demonstrated that up until about age 20 there is an increase in VO_2max and anaerobic threshold with the increase in the volume of low intensity prolonged training. Further increase is more connected with intensity of training [8,17,24].

One possibility for the intensification of training in cross-country skiers is the effectively performed strength training [8,10,21]. Recent studies [16,22] have demonstrated the importance of upper body power and endurance for the cross-country skiers. The evaluation of the impact of strength training on endurance performance is quite complicated. When the subjects are initially untrained or less trained, strength training can have a positive effect on endurance performance [13]. Trained athletes may have a narrower range for further beneficial adaptations and require greater task specificity to achieve continued improvement [11]. Bosco *et al.* [2] showed that skeletal muscle as specialized tissue modifies its functional capacity according to chronic exercise. During explosive type exercises it occurs mainly neurogenic and myogenic components respond, in endurance exercises cardio-respiratory, circulatory and metabolic adaptations occurs.

Cross-country skiers are using the strength exercises for different purposes – for development of maximal strength, power, strength- and muscle endurance. Experienced athlete does not train strength as an universal whole, but its single components – energetical, muscular or neural. Therefore, it is very important to select the suitable exercises to achieve planned results. Zatsiorski [25] claims that the most important part of the strength development in endurance events is to enhance the force generated by the slow motor units, which are highly adapted to lengthy aerobic muscular work, consequently, the main attention will be devoted to strength endurance and muscular endurance [15,23]. At the same time the strength development of slow twitch fibres strength will create good presumption for successive or concurrent enhancement of anaerobic threshold speed.

For the evaluation of training load influence, the heart rate and respective intensity zones are extensively used. Welde and Vikander [24] classified all endurance training in cross-country skiers using a five-level intensity scale

(Table 1). The low intensity training was mainly carried out at 60-75% of the maximal heart rate and high intensity training at 85-95% of the maximal heart rate. The upper part of this intensity zone is well above lactate threshold of the subjects.

Table 1
Training intensity zones of Norwegian male junior cross-country skiers (Welde, Vikander, 2000)

Intensity zone	HR as % of HRmax	HR(beats·min^{-1})
1	60 – 75	120 – 150
2	75 – 85	150 – 170
3	85 – 90	170 – 180
4	90 – 95	180 – 190
5	95 – 100	190 – 200

Many researchers [3,5,6] have shown that heart rate is a good index of general health and fitness and provides information on the reactions to environmental conditions, stress, diseases and fatigue. The lactate measurements help to evaluate metabolic processes in muscles and direct the way of good performance [1,14]. Training programs for groups rarely work properly as every sportsman is individually different [9]. Consequently, concrete individual advices should be given to every member of the training group.

Heart rate testers and lactate analyzers have widely been used to guide cross-country skiing training. We hypothesized that the metabolic influence of endurance and strength endurance exercises may be different despite similar heart rate values.

The purpose of this study was to evaluate the metabolic changes of strength endurance exercise complex in young cross-country skiers using heart rate and blood lactate concentration indices and compare these changes with those occurring in the organism when performing a running load at the level of anaerobic threshold. In addition, the suitability of this exercise complex in the training of young cross-country skiers was assessed.

Materials and Methods

Subjects: Ten young male cross-country skiers (17.2±2.2 yrs; 174.7±8.6 cm; 62.3±8.7 kg) participated in the study in preparatory period in May on their written informed consent. The study was approved by the Medical Ethics Committee of the University of Tartu (Estonia).

Design: Modified strength endurance exercise complex developed by Finnish specialist Elevaara [4] was performed in indoor conditions. Complex consisted of 12 strength endurance exercises in moderate intensity, including the exercises for legs, hands, abdomen and back (Fig. 1). Most of exercises were performed in sets of 2x40 sec with recovery period of 20 s between the sets. As an exception the 2nd, 4th, 5th and 8th exercises were performed in one set and the duration of exercise was 2 min. Recovery interval between different sets was 30 s. After strength endurance exercise complex followed a 5 min recovery period. After that the subjects passed 10 laps (1500 m) on indoor track with individually controlled heart rate of 170-180 beats·min^{-1}, which corresponded to their anaerobic threshold levels. Five min recovery period followed the running load.

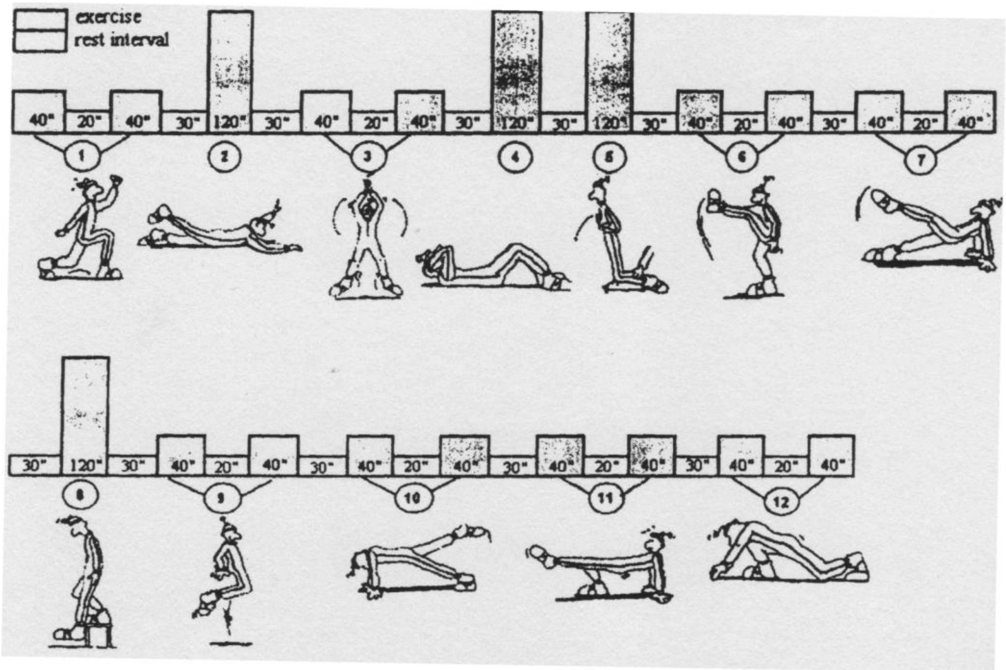

Fig. 1
Strength endurance exercise complex design

Procedures: Heart rate was measured continuously with Polar Vantage NV Sporttester (Polar Electro OY, Kempele, Finland). Capillary blood samples of 10 μl were obtained by fingertip stick procedure immediately after 6th, 10th and 12th exercise and after 1500 m run and at the 5th recovery minute after the strength exercise complex and running load. Blood lactate concentration was analysed immediately enzymatically in duplicate with a Lange (Germany) analyzer in $mmol \cdot l^{-1}$ with 0.01 $mmol \cdot l^{-1}$ accuracy. For the evaluation of special performance level ranking was used. This was done by 3 coach-experts, who knew athletes very well. Each expert ranked all the 10 subjects and the 1st place got to 10 points, the 2nd place 9 points, and the 3rd place 8 points, etc. The final ranking was determined by the mean of the ratings of the all three experts. The criteria of rating included the results of the last competitions of the winter season and control exercises, as well as their stability

Statistical analysis: Descriptive statistics (Mean±Standard Deviation [SD]) for every dependent variable was calculated. Pearson correlation coefficients were calculated between dependent variables. Statistical significance was set at $p<0.05$.

Results

Results of study are presented in Table 2 and Fig. 2. For the evaluation of strength endurance exercise complex total influence mean values of heart rate and blood lactate concentration after 6th, 10th and 12th exercise were analysed. Mean heart rate range 156-168 $beats \cdot min^{-1}$, showed that the complex was in the second intensity zone [24]. Blood lactate concentrations after the same exercises was in the range of 5.00-6.10 $mmol \cdot l^{-1}$, which is slightly more than classical 4 $mmol \cdot l^{-1}$ for the anaerobic threshold level. The 1500 m run, done after the strength exercise complex, increased mean heart to 170.7±4 $beats \cdot min^{-1}$ and mean blood lactate concentration to 2.70±0.75 $mmol \cdot l^{-1}$, i.e. the run was aerobic.

The correlation analysis revealed a significant relationship between the ranking and the heart rate after the 2nd, 4th, 5th, 9th, 11th and 12th exercise (r=0.62 – 0.80) (Fig. 2). Statistically significant correlations were obtained between the ranking and blood lactate levels after the 10^{th} and 12^{th} exercise and in the 5th minute of recovery. The ranking correlated highly with the mean running time of 1500 m bout (r=0.90). Reasonably high correlation was seen between the heart rate and lactate concentrations after the 10^{th} and 12^{th} exercise (r=0.78 and r=0.89). There was a very high correlation between heart rate after the strength exercise complex and lactate concentration level in the 5^{th} recovery minute.

Table 2
Heart rate (HR) and blood lactate concentration (BLA) indices and their recovery in the evaluation of strength endurance exercise complex influence on young cross-country skiers (M±SD)

Index	M	SD
HR after 6th exercise (beats·min^{-1})	156.5	15.1
HR after 10th exercise (beats·min^{-1})	165.4	14.6
HR after 12th exercise (beats·min^{-1})	167.9	10.8
BLA after 6th exercise (mmol·l^{-1})	5.00	1.05
BLA after 10th exercise (mmol·l^{-1})	6.10	1.25
BLA after 12th exercise (mmol·l^{-1})	5.90	2.70
BLA at 5th recovery minute (mmol·l^{-1})	4.55	2.20
HR at 5th recovery minute (beats·min^{-1})	109.5	11.4
Mean time of 150 m bout (sec)	43.4	5.9
Mean HR of 1500 m run (beats·min^{-1})	169.7	3.9
BLA after 1500 m run (mmol·l^{-1})	2.70	0.75
BLA at 5th recovery minute (mmol·l^{-1})	2.15	0.50

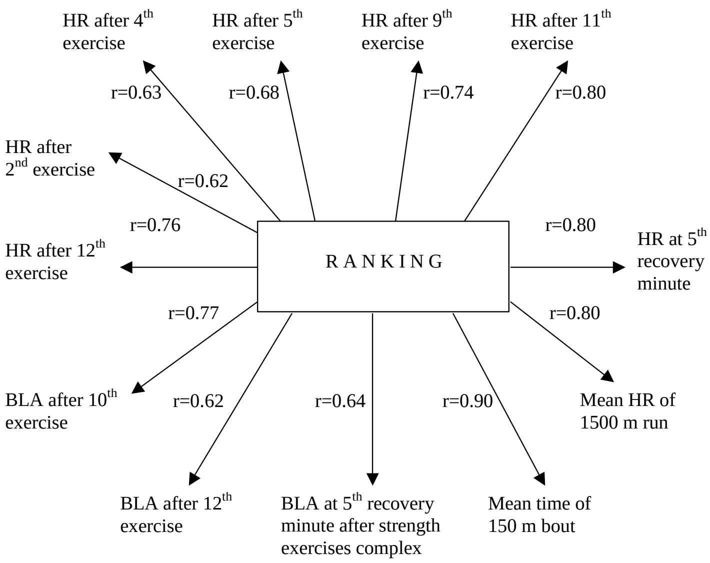

Fig. 2
Correlations between ranking and registered indices of young cross-country skiers

Discussion

The most important finding of the present study was that the metabolic reaction during the strength endurance exercise complex and running at anaerobic threshold level in the same training session was very different. This was supported by a quite similar mean heart rates after the strength exercise complex and running (168±11 and 170±4 beats·min^{-1}, respectively) and very different blood lactate concentrations (5.90±2.70 and 2.70±0.75 mmol·l^{-1}, respectively). Consequently, by not evaluating the metabolic state of muscles, which is based on blood lactate concentration, we may get a wrong picture about the influence of different training loads in young cross-country skiers.

Lactate concentration after strength exercise complex convincingly showed that work was performed in mixed aerobic-anaerobic zone but lactate concentrations after running load corresponded to the zone between aerobic and anaerobic threshold. As this study took place in the beginning of preparatory period, the mean lactate concentration of investigated group was relatively high and for this reason the intensity of the whole complex was similarly high. On this occasion the fast oxydative muscle fibres were also switched in work and more lactate was produced. Somewhat smaller intensity, major volume and preferable influence on slow twitch fibres are appropriate for this training stage. This recommendation is in good accordance with earlier findings [15,25].

The heart rates during 1500 m run were relatively high (169.7±3.9 beats·min^{-1}), still remaining in the second intensity zone by Welde and Vikander [24]. However, the lactate concentration immediately after the running load was adequate (2.70±0.75 mmol·l^{-1}) to training tasks in the beginning of preparatory period. Running training with such an intensity is appropriate for maintaining aerobic working capacity and to further develop aerobic basis. For giving more detailed advices individual indices of heart rate and blood lactate concentrations should be used.

Correlation analysis revealed that lower ranking order significantly correlated with the higher heart rates after different strength exercises (r=0.62-0.80). It is well known that better economy is achieved when performing standard exercises with lower heart rate. Ranking was significantly correlated with lactate concentration after the 10th and 12th strength exercises and with lactate level at the 5th min of recovery after the complete of strength exercises complex (r=0.62-0.77). Therefore, ranking was significantly influenced by heart rates after the different strength exercises and lactate concentration levels at the end and after the recovery pause following strength exercise complex. It is possible to get valuable information about adaptational and metabolic changes in skiers and help the guidance of training process when using heart rate and blood lactate concentration indices after standard strength endurance exercise complex.

The quality of anaerobic threshold speed was evaluated by the mean 1500 m running bout result, which was obtained at the mean heart rate of 170 beats·min^{-1}. As it is supposed, skiers' ranking correlated significantly with both the mean 150 m bout result and the mean heart rate during 1500 m run. Better performers were those who could run faster at the level of anaerobic threshold and maintain the heart rate at lower level during this run. Determining the speed of anaerobic threshold at the same training unit with strength endurance exercise complex we can compare the changes in the two most important components of skiers' performance – strength endurance and aerobic capacity [23].

High correlation (r=0.92) between the heart rate at the end of strength exercise complex and blood lactate concentration at the fifth recovery minute showed that the higher heart rates at the end of complex caused significantly poorer blood lactate recovery speed. But there was contradiction between the good recovery of heart rate (up to 109 beats·min^{-1}) and relatively high level of the blood lactate concentration (4.5 mmol·l^{-1}) at the same time. Monitoring only heart rate recovery we can underestimate muscles' metabolic state and maybe plan excessive strength training complex intensity for the concrete training stage.

Too excessive strength exercise intensity may have a negative influence on the anaerobic threshold speed which is not the purpose at the transition period either in the development of aerobic performance basis at the preparatory period [25]. By testing the strength endurance and anaerobic threshold speeds concurrently we can find optimal balance between both developments. We can conclude that the standard strength exercise complex with the running load on aerobic threshold level in the same training session can be used in testing of young cross-country skiers in the summer period.

Favourable changes in the influence of strength endurance exercises complex and in quality of anaerobic threshold speed are the indices of effective base training.

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