Introduction
Successful endurance training involves the manipulation of training intensity, duration and frequency, with the implicit goal of maximizing performance. Several studies have suggested that high-intensity endurance training is effective for improving aerobic characteristics and endurance performance in highly trained endurance athletes. However, the manipulation of intensity and duration within these high-intensity sessions may play an important role for the endurance adaptations. The purpose of this study was to investigate the effects of short and long durations aerobic high-intensity intervals at different intensities on endurance performance and aerobic characteristics in elite athletes.

Methods
21 elite junior cross-country skiers performed an 8-week baseline and an 8-week intervention training period with interval training descriptions differing in intensity and duration based on isoeffort matching. During the intervention period, a short interval training group (SIG, n=7) increased the volume of short duration intervals (1- to 4-min bouts with a total duration of 15-20 min) at ~95% of maximum heart rate (HRmax), a long interval training group (LIG, n=7) increased the volume of long duration intervals (5- to 10-min bouts with a total duration of 40-45 min) at ~90% of HRmax, whereas a control group (CG, n=7) continued their baseline training distribution. The skiers were tested for time-trial performance on 12 km roller-ski skating and 7 km hill run in pre- and post-tests. Maximal oxygen uptake (VO2max) and oxygen uptake at the ventilatory threshold (VO2VT) were measured during treadmill running.

Results
- The LIG improved performance in both 12 km roller-skiing and 7 km hill run from pre- to post-testing by ~7% and 5% respectively.
- The SIG and LIG improved VO2max by ~3.5% from pre to post-testing (both p < 0.01), whereas the performance in the CG did not change significantly.
- The LIG improved VO2VT by ~6% from pre to post-testing (p = 0.004), whereas VO2VT in the SIG and CG did not change significantly.

Discussion
This study highlights the positive effects of aerobic high-intensity endurance training, and specifically emphasizes long duration intervals at an intensity slightly above the anaerobic threshold for improving endurance performance in cross-country skiers. Overall, intensity and duration appear to be integrated as signaling components in the adaptive response to high-intensity endurance training in elite endurance athletes. Long duration intervals at an intensity slightly above the anaerobic threshold was superior to short duration intervals for improving endurance performance in cross-country skiers.