

Research article

Effects of high intensity training and continuous endurance training on aerobic capacity and body composition in recreationally active runners

Kuno Hottenrott^{1,2}✉, Sebastian Ludyga² and Stephan Schulze^{1,2}

¹ Department of Sport Science and ² Institute of Performance Diagnostics and Health Promotion, Martin-Luther-University Halle-Wittenberg, Germany

Abstract

The aim of the study was to examine the effects of two different training programs (high-intensity-training vs. continuous endurance training) on aerobic power and body composition in recreationally active men and women and to test whether or not participants were able to complete a half marathon after the intervention period. Thirty-four recreational endurance runners were randomly assigned either to a Weekend-Group (WE, $n = 17$) or an After-Work-Group (AW, $n = 17$) for a 12 week-intervention period. WE weekly completed 2 h 30 min of continuous endurance running composed of 2 sessions on the weekend. In contrast, AW performed 4 30 min sessions of high intensity training and an additional 30 min endurance run weekly, always after work. During an exhaustive treadmill test aerobic power was measured and heart rate was continuously recorded. Body composition was assessed using bio-impedance. Following the intervention period all subjects took part in a half-marathon. AW significantly improved peak oxygen uptake (VO_2 peak) from 36.8 ± 4.5 to 43.6 ± 6.5 [$mL \cdot min^{-1} \cdot kg^{-1}$], velocity at lactate threshold (V_{LT}) from 9.7 ± 2.2 to 11.7 ± 1.8 [$km \cdot h^{-1}$] and visceral fat from 5.6 ± 2.2 to 4.7 ± 1.9 . In WE VO_2 peak significantly increased from 38.8 ± 5.0 to 41.5 ± 6.0 [$mL \cdot min^{-1} \cdot kg^{-1}$], V_{LT} from 9.9 ± 1.3 to 11.2 ± 1.7 [$km \cdot h^{-1}$] and visceral fat was reduced from 5.7 ± 2.1 to 5.4 ± 1.9 ($p < 0.01$). Only the improvements of VO_2 peak were significantly greater in AW compared with WE (pre/post group interaction: $F=15.4$, $p = 0.01$, $\eta^2 = 0.36$). Both groups completed a half marathon with no significant differences in performance ($p = 0.63$). Short, intensive endurance training sessions of about 30 min are effective in improving aerobic fitness in recreationally active runners.

Key words: Aerobic power, lactate threshold, VO_2 peak, endurance running, aerobic training.

Introduction

Regular endurance training improves physical fitness and recovery rate (Sloan et al., 2011). The American College of Sports Medicine (Haskell et al., 2007) recommends moderate-intensity aerobic exercise for a minimum of 30 min on five days each week or vigorous-intensity aerobic physical activity for a minimum of 20 min on three days each week to all healthy adults aged 18 to 65 yr. Many people already know about the health benefits of endurance training and try to establish it as a part of daily life. Nevertheless, working people fail to perform training regularly mainly due to a lack of time (Booth et al., 1997). Therefore, it is necessary to provide them with training programs, which promote aerobic fitness and health as well as performance. The question arises whether working

people would rather benefit from longer, less frequent (classic model of continuous endurance training) or shorter, more frequent training sessions (high intensity training).

The latter is characterized by relatively short, intermittent loads at sub maximal or maximal intensity. Gosselin et al. (2011) showed that 5 bouts of high intensity training (HIT) are no more physiologically taxing than 20 min steady state exercise performed at 70 % VO_2 max, so that HIT might be safe and suitable for recreationally active people as well. Depending on intensity the load can vary from some seconds to several minutes, followed by a few minutes of rest or an exercise phase at low intensity (Boutcher, 2011; Gibala, 2009). A whole training session can take 20 to 40 minutes. Some studies already revealed that HIT leads to improvements of both aerobic and anaerobic fitness (Whyte et al., 2010). Talarian et al. (2007) showed that 2 weeks of HIT led to an increase of VO_2 max of 7 to 12%. Depending on the age and fitness level of the subjects as well as the duration and intensity of the intervention improvements of VO_2 max from 4 to 46% have been reported (Burgomaster et al., 2008; Helgerud et al., 2007; Perry et al., 2008; Tremblay et al., 1994; Warburton et al., 2005). All studies mainly included healthy, young athletes. Consequently, there is still a lack of studies confirming the efficacy and the health relevance of HIT in people that are recreationally active or at an older age. For these target groups there are also no scientifically substantiated information of the dose-response relationship of HIT.

The purpose of the present study was to provide recreational endurance runners with two training programs that promote health and enhance performance. Therefore, we examined the effects of HIT and continuous endurance training on aerobic fitness and body composition in less trained subjects. In addition, to investigate the influence of both training methods on performance participants completed a half marathon. The training volume for both programs was about 2 h 30 min per week. We hypothesized that the group performing a HIT would improve aerobic fitness more than the group carrying out continuous endurance training.

Methods

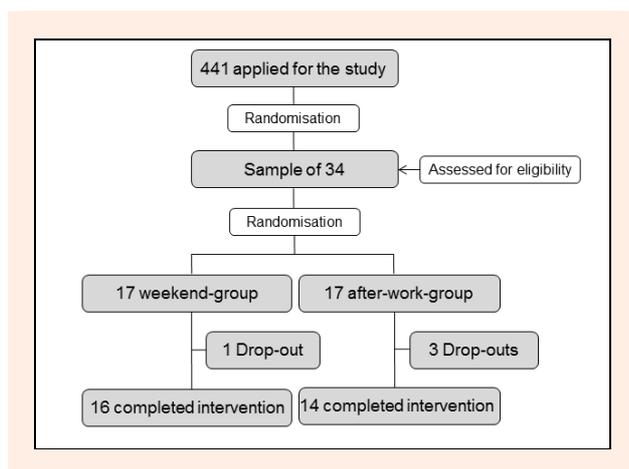
Subjects

Recreational endurance runners were recruited for a 12-week aerobic training program through advertisements in a local newspaper. Subjects had to be employed and non-

Table 1. Anthropometric measures of study participants. Data are means (\pm SD).

	AW		WE		All
Gender	♂	♀	♂	♀	♂+♀
N	7	7	8	8	30
Age [years]	42.4 (6.4)	41.7 (8.4)	43.8 (7.2)	45.6 (4.9)	43.4 (6.9)
Body mass [kg]	72.7 (7.2)	64.1 (6.6)	77.0 (7.4)	62.3 (4.5)	70.5 (8.9)
Body height [cm]	1.73 (.04)	1.67 (.06)	1.77 (.04)	1.65 (.05)	1.71 (.07)
BMI [kg·m⁻²]	24.1 (3.9)	22.9 (1.8)	24.5 (4.1)	22.9 (1.9)	23.9 (2.0)

smokers. Their training had to consist of 1 to 2 hours moderate endurance exercise including 5 to 10 km total running distance per week for at least six months prior to the intervention. Due to laboratory constraints a sample of 34 participants (Table 1) were selected at random from 441 people that submitted a written application to participate the study (Figure 1). Only the sample ($n = 34$) was assessed for eligibility and then randomized either to the weekend-group (WE), which performed 2 sessions of continuous endurance training on the weekend, or the after-work-group (AW), which conducted 4 sessions of high intensity training and an additional endurance run per week, always following work. After the intervention the participants took part in a half marathon.

**Figure 1. Distribution of study participants.**

Subjects were fully informed about the study design, including information on the possible risks and benefits. They all signed an informed consent form to participate in the study. Subjects received initial medical screening followed by the assessment of blood pressure, ECG measurement before and after exertion as well as the collection of anthropometric data (Table 1). Exclusion criteria were any cardiovascular, metabolic, neurological, pulmonary or orthopedic complications that could limit completion of the training programs. The study was approved by the Ethics Committee of the Martin-Luther University Halle-Wittenberg, Germany (08-03-2011).

Test protocol

Pre and post-tests were carried out at the same time and day of the week. Nutrition and fluid intake prior to the tests were also standardized. Furthermore, investigators were blinded to the treatments during data collection. Body composition (total body fat, total muscle mass, visceral fat) was measured using a bio impedance device (Tanita, model BC-545 Inner-Scan, Germany). Cardio-

vascular fitness (VO_2 peak) was also assessed at baseline and after the intervention using a treadmill stage test and spirometry (Cortex, model Metamax 3b, Germany): Every 3 min the speed increased by 1.5 km h^{-1} starting from 7.5 km h^{-1} in the first stage until objective exhaustion ($RER > 1.1$ or the inability to keep up the belt speed). After each stage lactate levels were measured with the enzymatic-amperometric method (Dr. Mueller, model Super GL ambulance, Germany) in $10 \mu\text{L}$ blood taken from an ear lobe. According to Dickhuth et al. (1988) the lactate threshold was defined as the lowest value of the quotient $[(\text{mmol L}^{-1})(\text{km h}^{-1})^{-1}]$. Collected data were analyzed with WinLactat 3.1 (Mesics GmbH, Germany) to determine training zones by means of the lactate/speed curve. Following the model of Dickhuth (1988) the training zones were set at 75% (basic endurance training) and at 85% of the velocity (advanced endurance training) of the lactate threshold (V_{LT}).

Training

In both groups the training program was progressive and carried out on the same, flat course in groups of 3 to 4 people. The WE weekly completed 2 sessions of continuous endurance running on the weekend. In order to prepare the AW for high-intensity training, there was a phase of 4 sessions of continuous running at 60 to 70% V_{LT} . Afterwards, the AW performed 4 30 min sessions of high intensity training and an additional endurance run weekly throughout the intervention. The intensity zones and the interval training programs were set individually for every session (Table 2). For both groups the training load was about 2 h 30 min weekly and exercise guidelines were determined in relation to the V_{LT} , which was calculated with the data obtained in the treadmill stage test. To encourage participants remain in the predetermined training zones they used portable heart rate monitors with a chest strap, which featured a running sensor to control velocity (Polar Electro, model FT-60 / WearLink, Finland), during training. Furthermore, the compliance to training guidelines was gauged by downloading the data saved on the heart rate monitors.

Statistical analysis

Subjects with incomplete data ($n = 4$) were excluded from the statistical analysis, which was performed with SPSS Statistics 19.0. To evaluate whether or not the data were normally distributed the Kolmogorov-Smirnoff test was applied. In case of normal distribution, Student's t-test for paired samples was used for an inter-group-comparison. To calculate possible interaction effects between groups a two-factor ANOVA with repeated measures on the second factor was applied. Independent post-hoc t-tests were used for an inter-group-comparison. The level of signifi-

Table 2. Weekly training guidelines for AW and WE.

	AW (2 h 30 min)	WE (2 h 30 min)
Monday	30 min endurance running at 85% V_{LT}	-
Tuesday*	10 intervals of 30 second all-out sprints, each followed by running at about 85% V_{LT}	-
Wednesday	30 min intensive endurance running at 100% V_{LT}	-
Thursday*	4 to 6 intervals of 2 min running at maximal speed reached during treadmill stage test, each followed by 90 s running at about 85% V_{LT}	-
Friday*	10 intervals of 30 sec sprints, each followed by 90 seconds of running at 85% V_{LT}	-
Saturday	-	30 to 60 min endurance running at 85% V_{LT}
Sunday	-	60 to 120 min endurance running at 75% V_{LT}

*=plus 5-10 min warm up und cool down running

cance was set at $p \leq 0.05$. The following variables were selected to identify significant changes within the groups: body mass [kg], body mass index [$\text{kg}\cdot\text{m}^{-2}$], total body fat [%], visceral fat [reference value: 1-12= healthy level, 13-49=excess level], fat free mass [kg], resting heart rate [$\text{beats}\cdot\text{min}^{-1}$], relative maximal oxygen uptake [$\text{mL}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$], maximal treadmill speed [$\text{km}\cdot\text{h}^{-1}$], velocity at lactate threshold [$\text{km}\cdot\text{h}^{-1}$], maximal lactate [$\text{mmol}\cdot\text{L}^{-1}$], resting RER and resting lactate [$\text{mmol}\cdot\text{L}^{-1}$].

Results

At baseline parameters of body composition, aerobic fitness and anthropometric measures were not significantly different between groups (Table 1). During the experimental period 4 subjects were unable to complete the intervention (Figure 1), one had an ankle joint injury (WE), one caught an infection and 2 withdrew for personal reasons (AW). Thus, 30 participants performed 91.9% of the scheduled weekly amount of 2 h 30 min. The adherence to training was not significantly different between groups (AW = 2 h 10 min \pm 21 min; WE = 2 h 19 min \pm 10 min; $p = 0.25$). There were no sex differences between groups, but improvements in aerobic power and body composition tended to be higher in men compared with women.

Body composition

The total body mass significantly decreased in AW and WE (Table 3). Consequently, the BMI changed from 23.9 to 23.3 $\text{kg}\cdot\text{m}^{-2}$ in AW and to 23.4 $\text{kg}\cdot\text{m}^{-2}$ in WE. Interestingly, for AW there was no significant reduction of fat free mass ($p = 0.27$) or total body fat. However, the vis-

ceral fat significantly decreased by 16.5%. In contrast, there was a significant loss of fat free mass, total body fat and 6.5% visceral fat in WE.

Heart rate

The resting heart rate significantly decreased in AW and WE (Figure 2A). Furthermore, the maximal heart rate during the treadmill stage test was also significantly lower in AW after the intervention compared with baseline ($p = 0.03$).

Aerobic power

Both AW and WE improved aerobic power (Figure 2B). The difference in peak aerobic power between groups was significant as there was an interaction effect (pre/post group interaction: $F=15.4$, $p = 0.01$, $\eta^2 = 0.36$). The velocity at lactate threshold (Figure 2C) was significantly higher in both groups after the intervention. However, there was no significant difference between AW and WE (pre/post group interaction: $F=3.6$, $p = 0.07$, $\eta^2 = 0.11$). Maximal lactate, resting lactate and resting-RER did not change significantly over the intervention period.

Half-marathon

All subjects, who took part in the half-marathon (AW = 10; WE = 14), completed it successfully. Times were 02:14:37 \pm 00:21:28 [hh:min:sec] (AW) versus 02:17:15 \pm 00:19:24 [hh:min:sec] (WE) respectively ($p = 0.63$).

Discussion

Body composition

A significant decrease of fat free mass, total body fat and

Table 3. Parameters of body composition, aerobic power and heart rate in AW and WE before and after the intervention period. Data are means (\pm SD).

	AW (N = 7♂ / 7♀)			WE (N = 8♂ / 8♀)		
	Pre	Post	p-Value	Pre	Post	p-Value
Body mass [kg]	70.5 (8.1)	67.6 (7.1)	.01	70.5 (9.8)	68.7 (8.9)	.01
Total body fat [%]	22.5 (6.3)	21.0 (6.6)	.09	22.4 (6.3)	21.4 (6.5)	.02
Visceral fat [kg]	5.6 (2.2)	4.7 (1.9)	.01	5.7 (2.1)	5.4 (1.9)	.01
Fat free mass [kg]	51.8 (7.3)	50.8 (7.4)	.27	52.1 (9.3)	51.4 (8.7)	.02
Resting HR [$\text{b}\cdot\text{min}^{-1}$]	65.8 (11.5)	57.8 (13.0)	.01	70.1 (12.3)	60.6 (7.6)	.01
Rel. VO_2 peak [$\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$] #	36.8 (4.5)	43.6 (6.5)	.01	38.8 (5.0)	41.5 (6.0)	.01
Maximal speed [$\text{km}\cdot\text{h}^{-1}$]	11.9 (1.6)	13.9 (2.1)	.01	12.8 (1.8)	14.0 (1.9)	.01
Maximal lactate [$\text{mmol}\cdot\text{L}^{-1}$]	7.6 (2.2)	7.9 (2.2)	.39	8.7 (2.0)	9.2 (2.2)	.31
VLT [$\text{km}\cdot\text{h}^{-1}$]	9.7 (2.2)	11.7 (1.8)	.01	9.9 (1.3)	11.2 (1.7)	.01
Resting RER	.78 (.09)	.78 (.06)	.77	.79 (.07)	.78 (.07)	.57

#= pre/post group interaction: $p=0.01$, $\eta^2=0.36$ leaa

visceral fat resulted in an overall reduction of total body mass in WE. Although the decrease of body mass was identical in AW, it appears this was mainly caused by a 16.5% reduction of visceral fat. These results suggest that HIT may be more favourable for weight loss in terms of visceral fat. The findings of the present study were similar to those reported by Tremblay et al. (1994), namely that high-intensity intermittent exercise training induced greater visceral fat loss compared to moderate-intensity exercise. Slentz et al. (2004) also showed that there was a dose-response relationship of training volume and loss of body fat, suggesting that a higher amount of training leads to greater reductions.

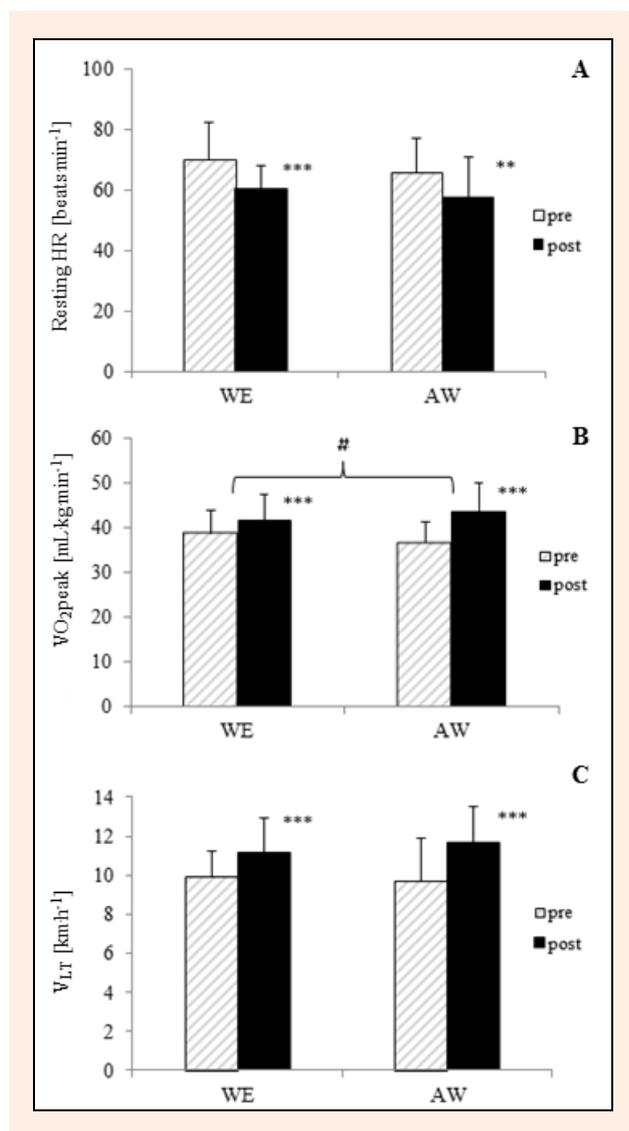


Figure 2. Effects of 12 week continuous endurance training (WE) and high intensity training (AW) on resting HR (panel A), VO₂peak (panel B) and V_{LT} (panel C) in recreationally active runners. ** = pre/post: $p < 0.01$; *** = pre/post: $p < 0.001$; # = pre/post group interaction: $p = 0.01$, $\eta^2 = 0.36$.

Earlier studies also state that the total energy expenditure is a key factor for inducing fat loss (Grediagin et al., 1995; Slentz et al., 2004). As AW and WE had the same training volume, either the higher intensity or greater frequency of training may be the reason for

slightly greater changes. It is likely that the energy expenditure in AW was higher, because they benefited from excess post-exercise oxygen consumption (EPOC) on 5 days compared to 2 days at the WE. Borsheim and Bahr (2003) have shown that the absence of a sustained EPOC is connected with lower exercise intensities, which are similar to those in WE. In contrast, there is a linear relationship between EPOC magnitude and exercise intensity (Laforgia et al., 2006).

However, both training methods resulted in improvements of body composition and weight, although AW and WE already had a healthy BMI at baseline (23.9 kg·m⁻²). As visceral fat is a risk factor for cardiovascular diseases (Romero-Corral et al., 2010; Sironi et al., 2012), the reduction through either HIT or continuous endurance training is a relevant health benefit.

Heart rate

In both groups the resting heart rate was reduced significantly after completing the intervention period, inter alia through improved efficiency of peripheral muscles and higher stroke volume. Recent studies (Kemi and Wisloff, 2010; Wisloff et al., 2009) showed that high-intensity aerobic exercise is associated with greater cardiac benefits than exercise at low to moderate intensity. Whereas Cornelissen et al. (2010) showed that the effect of training especially on resting heart rate is greater at higher intensity the results of the present study confirmed a similar reduction of the resting heart rate in both AW and WE. Consequently, both training methods led to favourable health benefits as epidemiological studies showed that a higher resting heart rate is associated with an increased risk of death from either cardiovascular or noncardiovascular causes in middle-aged to elderly persons (Cooney et al., 2010; Tverdal et al., 2008).

Aerobic power

Subjects' relative peak oxygen uptake was significantly improved through both high-intensity training and continuous endurance training. This might be due to increases in oxygen delivery as well as improved oxygen utilization by active muscles through greater capillarization and mitochondrial density. As AW improved relative peak oxygen uptake by 18.6% compared to 7.1% in WE, the increase seems to be related to the training stimulus. A training program requiring a higher oxygen delivery leads to greater adaptations of the oxygen delivery system, e.g. through increased stroke volume and cardiac output (Esfarjania and Laursen, 2007). Thus, AW improved VO₂peak to a greater extent compared with WE perhaps due to more frequent training at higher intensities. These results are consistent with the findings of Gormley et al. (2008) and Helgerud et al. (2007), who both showed that high-intensity training compared to continuous endurance running shows a greater increase in maximal oxygen uptake.

The velocity at lactate threshold improved by 20.5% in AW and 12.9% in WE after completing the intervention. This rightward shift of the lactate-velocity curve in both groups also indicates an improvement in aerobic fitness. An increased mitochondrial enzyme con-

tent (Messonnier et al., 2002), which leads to a higher lipid utilization and a lower glycogen depletion, as well as raised capillary density are possible reasons for the improvement of the velocity at lactate threshold over the intervention period.

The results of the present study showed that both high-intensity-training and continuous endurance running led to increases of the aerobic power. Although greater improvements can be achieved by performing high-intensity training, it is interesting that only two weekly training sessions at moderate intensity also had a performance enhancing effect. According to Oja et al. (2011) increased aerobic power is related to benefits in cardiovascular risk factors, fitness and all-cause mortality. Furthermore, in a systematic review Swain and Franklin (2005) showed that higher training intensities convey greater cardioprotective benefits than exercise at lower intensity, even if the energy expenditure is the same in both methods.

Half-marathon

The time to finish the half-marathon was not significantly different between the groups. Given that the continuous endurance training in WE was much more similar to the conditions in a half-marathon, it is interesting that the high-intensity training enabled the AW to complete the run with no difference in performance. This could be due to the fact that there was no difference between AW and WE in the velocity at lactate threshold. Nevertheless, both training methods were effective to enable subjects to successfully finish a half-marathon after 12 weeks of training.

Limitations

Improvements of body composition might not only be due to HIT or continuous endurance training, because it is possible that participants changed their nutritional behaviour over the intervention period. Whether or not subjects changed their nutrition substantially remains unclear, because energy intake was not quantified in the present study and there was no information on how the appetite was influenced by the training program.

Another limitation of the study was that aerobic power was measured in a stage test only. On the one hand the influence of the two training programs on performance over 2 h could consequently not be captured in the laboratory setting. On the other hand both groups had no difference in performance times during the half marathon, which lasted a similar time.

Furthermore, the impact of the variables training intensity and frequency cannot be evaluated independently as this study compares two training interventions with the same total work duration. Seiler and Tennessen (2009) concluded that matching training programs by exercise duration seems sensible in a laboratory, because an athlete would rather adjust training variables according to perceived stress. However, the aim of the present study was to provide recreational endurance runners with two alternative training programs, which might meet any time constraints and promote their health as well as performance. So recreational endurance runners might compare

effects of different training programs based on total work duration.

Conclusion

The results of the present study indicate that high-intensity training as well as continuous endurance exercise led to significant improvements in body composition, resting heart rate and aerobic power with less than 2 h 30 min training weekly. Additionally, high-intensity training proved more effective in increasing relative peak oxygen uptake. Although slightly higher cardiorespiratory benefits seem to be conveyed with high-intensity training, both training methods seem to promote health. Therefore, recreationally active runners can choose to perform either 2 sessions of continuous endurance running on the weekend or 4 high intensity training sessions combined with an additional endurance run in the week in order to enhance their aerobic fitness and general health.

Acknowledgement

The authors declare that they had no competing interests.

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Key points

- Continuous endurance training and high intensity training lead to significant improvements of aerobic capacity and body composition
- Both training methods enable recreationally active runners to finish a half-marathon
- High intensity training is favorable to improve VO_2 peak

AUTHORS BIOGRAPHY



Kuno HOTTENROTT

Employment

Department of Sport Science, Martin-Luther-University Halle-Wittenberg, Germany & Institute of performance diagnostics and health promotion, Martin-Luther-University Halle-Wittenberg, Germany

Degree

Ph.D

Research interest

Aerobic training, sports nutrition, heart rate variability, exercise science

E-mail: kuno.hottenrott@sport.uni-halle.de



Sebastian LUDYGA

Employment

Institute of performance diagnostics and health promotion, Martin-Luther-University Halle-Wittenberg, Germany

Degree

M.A

Research interest

High intensity training, health promotion

E-mail: sebastian.ludyga@ilug.uni-halle.de

Stephan SCHULZE

Employment

Department of Sport Science, Martin-Luther-University Halle-Wittenberg, Germany & Institute of performance diagnostics and health promotion, Martin-Luther-University Halle-Wittenberg, Germany

Degree

Sports scientist (Ph.D. student)

Research interest

Applied fitness testing, exercise science

E-mail: stephan.schulze@sport.uni-halle.de

✉ Prof. Dr. phil. habil. Kuno Hottenrott

Department of Sport Science, Martin-Luther-University Halle-Wittenberg, Von-Seckendorff-Platz 2, 06120 Halle (Saale), Germany