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Author(s): Vesterinen, Ville; Nummela, Ari; Äyrämö, Sami; Laine, Tanja; Hynynen, Esa; Mikkola, Jussi; Häkkinen, Keijo

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Monitoring training adaptation with a submaximal running test in field conditions

Original Investigation

Ville Vesterinen¹, Ari Nummela¹, Sami Äyrämö², Tanja Laine¹, Esa Hynynen¹, Jussi Mikkola¹, Keijo Häkkinen³

¹KIHU – Research Institute for Olympic Sports, Jyväskylä, Finland

²Agora Center, University of Jyväskylä, Jyväskylä, Finland

³Department of Biology of Physical Activity, University of Jyväskylä, Jyväskylä, Finland

Corresponding author:

Ville Vesterinen, M.Sc.

KIHU - Research Institute for Olympic Sports

Address: Rautpohjankatu 6, 40700 Jyväskylä, Finland

Telephone: +358 50 545 1049

Fax: +358 20 781 1501

E-mail: ville.vesterinen@kihu.fi

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Abstract

Regular monitoring of adaptation to training is important for optimizing training load and recovery, which is the main factor in successful training. **Purpose:** The aim of this study was to investigate the usefulness of a novel submaximal running test in field conditions in predicting and tracking changes of endurance performance. **Methods:** Thirty five endurance trained men and women (aged from 20 to 55 years) completed the 18-weeks endurance training program. Maximal incremental running test was performed at weeks 0, 9 and 18 for determination of maximal oxygen consumption (VO_{2max}) and running speed (RS) at exhaustion (RS_{peak}) and lactate thresholds (LT). In addition, the subjects performed weekly a three staged submaximal running test (SRT), including a post-exercise heart rate recovery (HRR) measurement. The subjects were retrospectively grouped into four clusters according to changes in SRT results. **Results:** Large correlations ($r=0.60-0.89$) were observed between RS during all stages of SRT, and all endurance performance variables (VO_{2max} , RS_{peak} , RS at LT2 and RS at LT1). HRR correlated only with VO_{2max} ($r=0.46$). Large relationships were also found between changes in RS during 80% and 90% HR_{max} stages of SRT and a change of RS_{peak} ($r=0.57$, $r=0.79$). In addition, the cluster analysis revealed the different trends in RS during 80% and 90% stages during the training between the clusters, which showed different improvements in VO_{2max} and RS_{peak} . **Conclusions:** The present submaximal test showed great potential as a practical tool for regular monitoring of individual adaptation to endurance training without time-consuming and expensive laboratory tests.

Key words: endurance running, training, individual adaptation, SRT, predicting performance

Introduction

The crucial factor in successful training is the optimal balance between training load and recovery. If the training stimulus is too easy or if it is too demanding in relation to recovery, training may lead to undesirable adaptations. In addition, it is widely observed that individuals adapt differently to training load ¹⁻³. Regular e.g. weekly monitoring of changes in endurance performance during training is important for optimizing training load and recovery. However, regular monitoring is not useful to be conducted by maximal laboratory tests due to impracticality, expensiveness and interfering effects on normal training habits.

Decreased HR at submaximal exercise has been observed to be related to positive training adaptation ⁴⁻⁶. Thus, submaximal exercise HR may be an efficient method of assessing cardiac autonomic activity and tracking changes in maximal aerobic running speed. ⁴ Lamberts et al. ⁷ developed a submaximal cycling test for monitoring fatigue and predicting cycling performance. The authors found that cycling power at standardized submaximal HR levels and post-exercise heart rate recovery (HRR) can predict maximal cycling performance ^{7,8}, but less is known whether the submaximal test is able to reflect changes in endurance performance during a training period. In our previous study, we observed that HR / running speed (RS) – index, calculated from all constant speed running exercises, serves a potential tool for daily monitoring of training adaptation ⁹. However, there are many well-established factors (i.e. environmental factors, duration and intensity of exercise), which may influence on HR response, and thus, may disturb the relationship between HR and RS ^{10,11}. The HR-RS relation may provide more valid information about the training status, if the duration and intensity of exercise are standardized.

In addition to exercise HR, post-exercise HRR reflects cardiac autonomic activity, which has been suggested to be an important determinant of endurance training adaptation ^{4,6,8,12}. The measurement of post-exercise HRR has been proposed to have potential for monitoring fatigue and predicting changes in endurance performance parameters ^{4,8,12}. However, in previous studies related to submaximal tests and HRR have mainly been conducted in laboratory conditions. Less is known about the applicability of the tests as training monitoring tools in outdoor conditions. Therefore, the aim of this study was to investigate whether a novel submaximal running test in outdoor field conditions could be used in 1) predicting running performance and 2) monitoring changes in endurance performance during training. Based on the previous studies ^{4,12,13}, we hypothesized that running speeds at standardized HR levels and post-exercise HRR are able to predict endurance performance and monitor adaptation to endurance training ^{4,5}.

Methods

Subjects

Forty recreational endurance runners (20 women, 20 men) participated in the study. The subjects were healthy and had been training at least three times per week during the previous 6 months. General characteristics of the subjects are presented in Table 1. After being fully informed about the study design and the possible risks, all subjects completed an informed consent document. The study was approved by the Ethics Committee of the University of Jyväskylä, Finland.

Design and training

Training consisted of an 8-week low intensity endurance training period followed by an 8-week intensive training period. Maximal incremental treadmill running tests were performed before and

after both training periods (at weeks 0, 9 and 18). In addition, the subjects were instructed to perform weekly a submaximal running test (SRT) on an outside course. All testing was instructed to be performed at about the same time of day (within 2 hours).

The subjects were asked to train at low-intensity (below lactate threshold 1, LT 1) and maintain the same training volume (mean: 5.2 ± 1.9 times per week) as before the study during the first eight weeks. Thereafter, running training volume and intensity was increased during the following eight weeks. The training was periodized so that three weeks of intense training was followed by an easy training week. The subjects completed 1-3 moderate (30-40min, intensity between lactate thresholds (LT) 1 and 2) or high intensity interval (4x4 min with 4 min of recovery or 6 x 2 min with 2 min of recovery) or constant speed (20 min) training sessions with intensity above LT 2 per intense week. Endurance training consisted primarily of running but occasionally included also cycling, Nordic walking and/or cross-country skiing. The subjects were familiarized with the use of a Garmin FR 610 heart rate monitor (Garmin Ltd, Schaffhausen, Switzerland) and controlled their training intensity by measuring their HR during all exercises. In addition, the moderate and high intensity training sessions were supervised.

Maximal incremental treadmill running test

The subjects were asked not to do any vigorous physical activity two days prior to the maximal incremental treadmill running test. The subjects performed the running test for determination of maximal oxygen uptake (VO_{2max}), the peak treadmill running speed (RS_{peak}), LT2 and LT1 as described in the study of Vesterinen et al.³. The test started at 7 km/h for women 8 km/h for men and followed by the increase of 1 km/h every third minute until volitional exhaustion. The incline was kept at 0.5 degrees during the whole test. HR was recorded continuously with a heart rate monitor (Suunto t6, Suunto Ltd, Vantaa, Finland). Oxygen consumption was measured breath-by-breath throughout the test using a portable gas analyzer (Oxycon Mobile, Viasys Health Care, Würzburg, Germany). Blood samples (20 μ L) were taken from fingertip at the end of each load to analyze blood lactate concentrations (La) (Biosen S_line Lab+ lactate analyzer, EKF Diagnostic, Magdeburg, Germany). The maximal endurance performance was determined as the peak treadmill running speed (RS_{peak}) at exhaustion. If the subject could not complete the whole 3 min of the last speed, RS_{peak} was calculated as follows: speed of the last completed stage (km/h) + (running time (s) of the speed at exhaustion – 30 s) / (180-30 s) * 1 km/h. In the present study RS_{peak} was used as the main variable to describe the adaptation to endurance training during the training period.

Submaximal running test (SRT)

A submaximal running test (SRT) was modified from the Lamberts and Lambert Submaximal Cycle Test⁷. SRT was performed as a standardized warm-up protocol for moderate of high-intensity training sessions taking place after at least one easy training day. They were instructed to perform SRT once per week on the same outdoor course at each time. The 16-minutes SRT consisted of three stages (Figure 1). The subjects were asked to set their running speed (RS) according to HR corresponding to 70% (RS_1), 80% (RS_2) and 90% (RS_3) of a subject's maximum heart rate (HR_{max}) for 6, 6 and 3 minutes, by using Garmin FR 610 heart rate monitors with global positioning system (GPS) (Garmin Ltd, Schaffhausen, Switzerland). The target HRs were calculated based on HR_{max} in the maximal incremental treadmill test at week 0. A rate of perceived exertion with Borg's 0-10 scale¹⁴ was estimated after the last stage. HR and RS were recorded throughout the test but the data of the first minute of each stage was excluded from analyses due to setting RS to reach the target HR. Therefore, average RS and HR were calculated over a five minute period (1:00-6:00 and 7:00-12:00) for stage 1 and 2, and for a two minute period (13:00-15:00) for stage 3. After completing the running test, the subjects were asked to stand without moving and talking for 1 minute. They were asked to breathe normally, without controlling of the respiratory rate. Heart rate

recovery (HRR) was calculated by subtracting heart rate after 60 s recovery from heart rate at the end of third stage.

Statistical analysis

The results are expressed as means \pm standard deviations (SD). As the aim of the present study was to investigate usefulness of SRT in monitoring of individual adaptation to training, the subjects were retrospectively grouped into four clusters according to changes in the submaximal running test results. Due to the presence of missing data values (due to sicknesses, mild injuries or poor HR data) in time-series of RS1, RS2, RS3 and HRR, a self-implemented (MATLAB R2013a) variant of the classical K-means method¹⁵, in which missing values are handled using the available case strategy¹⁶, was applied in the cluster analysis. The detailed algorithmic description of the K-means method for incomplete data can be found in¹⁷. In order to avoid locally optimal cluster models, 1000 clustering models were generated for each set of time-series by using random restarts and the ones with the least sum of squared within cluster errors were selected for further analysis. Differences of changes in maximal running test between the clusters were analyzed using Kruskal Wallis test, followed by Dunn-Bonferroni post hoc method, due to small number of the subjects in the clusters. Pearson product moment correlation coefficient was used to determine the relationships between the absolute values of SRT and endurance performance variables at week 9, as well as between changes in SRT and endurance training adaptation after 18-weeks of training. In addition to measures of statistical significance, the following criteria were adopted to interpret the magnitude of the correlation between measurement variables: <0.1 (trivial), $0.1 - 0.3$ (small), $0.3 - 0.5$ (moderate), $0.5 - 0.7$ (large), $0.7 - 0.9$ (very large) and $0.9 - 1.0$ (almost perfect)¹⁸. Statistical significance was accepted as $P < 0.05$. Statistical analyses were carried out using SPSS software (IBM SPSS Statistics 20, IBM, New York, USA).

Results

Training

Five of the 40 subjects did not complete the study due to injuries ($n=4$) and lack of motivation ($n=1$). Training volume remained similar during both training periods (7.1 ± 2.6 h/week vs. 6.4 ± 2.0 h/week, 5.9 ± 2.1 sessions/week vs. 6.0 ± 2.1 sessions/week). Running volume increased for the second training period from 33 ± 17 km/week to 41 ± 16 km/week ($P < 0.001$). In addition, the percentage amount of high intensity training increased from $1 \pm 2\%$ to $4 \pm 3\%$ ($P < 0.001$), while the amount of low ($86 \pm 9\%$ vs. $84 \pm 9\%$) and moderate intensity ($13 \pm 8\%$ vs. $12 \pm 9\%$) training remained unaltered between the training periods.

Submaximal running test

The subjects were not able to perform SRT on every week due to sicknesses or mild injuries. In addition, some single test results were not approved to analysis due to poor HR signal. On average, they repeated SRT 13 times within 18 weeks. The presence of missing data values in the time-series of RS1, RS2, RS3 and HRR were 23.1%, 23.9%, 24.5% and 24.9%. The subjects were able to closely regulate their HR for the target HR levels by adjusting their RS according to GPS of the heart rate monitor. Mean HR for the three stages were $71 \pm 3\%$, $81 \pm 1\%$ and $90 \pm 1\%$ of HR_{max} . Individual mean ranges were 69 – 75% during the first, 77 – 84% during the second and 87 – 92% of HR_{max} during the third stage of SRT. Mean RPE after SRT was 5 ± 2 during the training period.

Predictors of endurance performance

Correlations between the results of SRT and endurance performance variables are presented in Table 2. Correlations between RS during all stages of SRT showed very large correlations with $\text{VO}_{2\text{max}}$, RS_{peak} , RS at LT2 and RS at LT1, but HRR correlated only with $\text{VO}_{2\text{max}}$. No differences were observed between sexes in the correlations, except HRR correlated with both $\text{VO}_{2\text{max}}$ and RS_{peak} in women ($r = 0.66$, $P = 0.003$, $r = 0.63$, $P = 0.005$), but not in men. A similar trend was found between HRR and $\text{VO}_{2\text{max}}$ ($r = 0.56$, $P = 0.073$) in men.

Relationships between changes in the submaximal running test and training adaptation

All endurance performance variables improved during the training period. $\text{VO}_{2\text{max}}$, RS_{peak} , RS at LT2 and LT1 improved by $2.2 \pm 6.2\%$ ($P = 0.043$), $3.2 \pm 4.0\%$ ($P < 0.001$), $5.7 \pm 4.6\%$ ($P < 0.001$) and $6.5 \pm 5.4\%$ ($P < 0.001$) (respectively). Relationships between the changes of variables in SRT and the changes of endurance performance variables after 18 weeks of training are shown in Table 3 and Figure 2. The changes in RS 2 and RS 3 of SRT correlated significantly with the change of $\text{VO}_{2\text{max}}$, RS_{peak} and RS at lactate thresholds. No sex differences were observed in the correlations.

Time series of the changes in RS of SRT for the clusters are presented in Figure 3. The clusters based on the change in RS 2, showed differences between the clusters in the change of $\text{VO}_{2\text{max}}$ ($P = 0.038$) and RS_{peak} ($P = 0.008$). The cluster 1, which showed the greatest improvement in RS 2, improved more in RS_{peak} compared with the clusters 2 and 3 ($P = 0.004$). The clusters grouped by the change of RS 3 showed also differences in the change of $\text{VO}_{2\text{max}}$ ($P = 0.009$) and RS_{peak} ($P = 0.004$) and RS at LT2 ($P = 0.042$). The clusters 1 and 2 showed significantly greater improvements in RS_{peak} compared with the clusters 3 and 4. The clusters grouped by the changes of RS 1, HRR and RPE, were not different according to the change of any endurance performance variables.

Discussion

The main finding of the present study describes the relationships between the changes of RS during the second and third stages of SRT, and the change in the endurance performance variables after the training period. In addition, the cluster analysis revealed different trends in RS of the second and third stages between the clusters, which also showed differences in the improvement of $\text{VO}_{2\text{max}}$ and RS_{peak} after the 18-week training period.

The subjects successfully regulated RS themselves for the target heart rate levels in outdoor conditions during SRT. The intensity of the third stage (90% of HR_{max}) seems to be the most reasonable for exact regulation of HR according to the small individual range of HR. These findings are in accordance with the previous studies related to submaximal running tests^{19,20}. SRT was designed to be as the standardized warm-up protocol for main training sessions, without interfering with normal training. Although all subjects were not able to do SRT on every week during the training period, due to sicknesses or mild injuries, they were able to repeat it regularly (mean: 13 times within 17 weeks). HR levels and RPE of the stages showed that the protocol of SRT was truly submaximal and did not cause remarkable training load, and thus is a suitable warming-up protocol for high intensity exercises.

Predictors of endurance performance

Very large correlations were found between the variables of SRT, especially RS 2 and RS 3, and RS_{peak} (Table 2). This finding suggests that running intensity should achieve the level of 80-90% of HR_{max} in order to predict maximal endurance performance variables ($\text{VO}_{2\text{max}}$, RS_{peak}), which supports the findings of Lamberts et al.⁷ and Otter et al.¹³. Previously slightly higher correlations were found between cycling power corresponding the intensity of 80% ($r = 0.88$) and 90% ($r =$

0.94) of HR_{max} and peak cycling performance⁷, and between rowing power at 90% of HR_{max} and 2000 m maximal rowing time ($r = -0.93$)¹³, which may be explained by more standardized testing conditions (laboratory) compared with the present study (outdoor conditions). In addition, we observed that the best predictor for RS at LT2 was RS at 80% of HR_{max} in SRT, and for RS at LT1 RS at 70% of HR_{max} . It is reasonable because RS of those stages are close to RS of the lactate thresholds. Post-exercise heart rate recovery (HRR) has been shown to reflect cardiac autonomic activity and training adaptation^{4,8,12}. In the present study, HRR after SRT correlated moderately with VO_{2max} , but not with endurance performance. The present finding supports that faster cardiorespiratory recovery after exercise is related to a greater aerobic capacity as reported by Daanen et al.²¹.

Monitoring of training adaptation

The main finding of the present study expressed that the changes of RS 2 and RS 3 in SRT were able to reflect changes in the endurance performance variables (VO_{2max} , RS_{peak} , RS at LT2, RS at LT1). In addition, the cluster analysis expressed that it is possible to identify the lowest and highest responders during the training based on the changes in RS at 80 and 90% of HR_{max} . Furthermore, the trends of the changes in RS at 90% of HR_{max} allow more exact identification of the amount of improvement in maximal endurance performance in the four clusters. Previously Buchheit et al.⁴ observed that the change in exercise HR during a submaximal running test at the 60% intensity of maximal aerobic speed were not different between responders and non-responders during an 8-week training. According to the present findings, intensity of 80-90 of HR_{max} is needed for monitoring the changes in the endurance performance variables during training. Previously, we observed that the change of HR-RS index measured from every continuous-type running exercise correlated moderately ($r = 0.43-0.61$) with the change of maximal running speed during the 28-week endurance training⁹. However, many external (such as duration and intensity of exercise) and internal factors (e.g. level of hydration, body temperature, cardiac drift) may disturb the use of relation between RS and HR^{10,11,22} as a tool to monitor training adaptation. The standardized duration and intensity of the protocol in the present study decreased possible disturbing factors and thus may explain larger correlations between the changes in RS of SRT and the change in the endurance performance variables in the present study compared with our previous findings⁹.

The novel present finding that RS in SRT can be used in monitoring of training adaptation, is based on the observations about the relation between decreased exercise HR and positive improvements in endurance performance^{4,6,9}. However, it has to be kept in mind that also negative training adaptation, in the case of short-term overreaching or overtraining, may be related to decreased exercise and HR_{max} ^{23,24}. On the other hand, RPE may increase at submaximal levels in overreaching or overtraining state because one should work harder for achieving the same HR level due to higher relatively intensity if HR_{max} is reduced²³. Therefore, RPE together with the data of RS give reasonable information about the training adaptation. In the present study, RPE remained stable in the clusters, which does not express any signs of overreaching.

Previously, Lamberts et al.¹² observed relationships between a change of HRR after 40 km cycling time trial and changes in maximal cycling performances ($r = 0.73 - 0.95$) after 4 weeks of high intensity training. Furthermore, HRR has been associated with the change of training load and endurance performance^{8,25}. In contrast to the previous studies, we did not observe any relationships between the change of HRR and the changes in endurance variables. Instead, our finding is in line with the studies of Buchheit et al.^{26,27} and Otter et al.¹³. The absence of the relationship can be explained by the relatively homogenous group of the subjects in the present study. It seems that the relation is weaker in homogenous groups¹³. The contradicting findings between the studies can also be explained with different protocols in the measurements, such as durations and intensities of

exercises, as well as time frames when HRR is measured. Future studies should focus more on the effects of methodological issues in measuring post-exercise HRR.

A limitation of the present study was a relatively small number of subjects. It did not allow systematical comparison between sexes. In addition, missing values due to sicknesses, injuries or incorrect data of HR or GPS in weekly SRT may cause some fluctuation in the trends because of large variation between individuals. Therefore, repeated ANOVA was not suitable as a statistical method. Instead, the cluster analysis was successfully performed with the missing values.

Practical Applications

Running speeds at 80 and 90% of HR_{max} were the most competent variables to reflect changes in maximal running performance during training, which were previously observed to predict endurance performance in cycling¹² and rowing¹³. Furthermore, monitoring the change in RS at 90% of HR_{max} serve the possibility to identify individuals who fail positive adaptation during training. That is an essential information for coaches and athletes to be able to adjust training program to achieve better outcomes. Regardless of the absence of the relation between the change in HRR and the training adaptation in the present study, HRR has been proposed to reflect the change in training load¹² and describe aerobic fitness²¹, like in the present study. Therefore, it is recommended that submaximal running test would include the measurements of RS (at 80 – 90% of HR_{max} intensities), post-exercise HRR and RPE for monitoring the status of the cardiorespiratory and cardiac autonomic regulation. The submaximal test shows great potential as a practical tool for regular monitoring of individual adaptation to endurance training in field conditions.

Conclusions

Running speed during SRT was able to predict maximal endurance performance. This study also showed that running speed at 80-90% HR_{max} during SRT was able to monitor endurance training adaptation in recreational endurance runners. Future studies should aim to test if individualizing of training program on the basis of SRT would be more productive compared to a traditional, predetermined training program.

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Tables:

Table 1. General characteristics of the subjects (mean ± SD).

	Women (n = 20)	Men (n = 20)
Age (y)	35 ± 10	35 ± 6
Height (m)	166 ± 7	175 ± 6
Weight (kg)	60.3 ± 7.3	77.3 ± 8.0
Body fat %	23.7 ± 4.4	15.2 ± 4.5
VO _{2max} (ml/kg/min)	47 ± 5	53 ± 5
Regular training background (y)	14 ± 8	14 ± 8
Training times/wk	5.6 ± 1.7	4.4 ± 2.0
Running km/wk	38 ± 19	27 ± 15

Body fat %, based on the sum of four skinfolds; VO_{2max}, maximal oxygen uptake; training times and running km, during the previous two months before the study.

Table 2. Correlation between the results of the submaximal running test (SRT) to endurance performance variables (n = 29).

	VO _{2max} (mL/kg/min)	RS _{peak} (km/h)	RS at LT2 (km/h)	RS at LT1 (km/h)
RS Stage 1 (km/h)	0.60*** ^b	0.74*** ^a	0.83*** ^a	0.87*** ^a
RS Stage 2 (km/h)	0.75*** ^a	0.83*** ^a	0.89*** ^a	0.83*** ^a
RS Stage 3 (km/h)	0.58*** ^b	0.79*** ^a	0.78*** ^a	0.71*** ^a
HRR (bpm)	0.46* ^c	0.22	0.31	0.22

Pearson's correlation, * $P < 0.05$, *** $P < 0.001$. ^a very large correlation, ^b large correlation, ^c moderate correlation.

VO_{2max}, maximal oxygen consumption; RS_{peak}, peak running speed in the maximal treadmill test; RS at LT2, running speed at lactate threshold 2; RS at LT1, running speed at lactate threshold 1; RS, running speed; HRR, heart rate recovery;

Table 3. Correlations between the changes in endurance performance variables and the changes in the submaximal running test (SRT, n = 26) after 18 weeks of training.

	VO _{2max} (%)	RS _{peak} (%)	RS at LT2 (%)	RS at LT1 (%)
RS Stage 1 (%)	0.34	0.24	0.27	0.34
RS Stage 2 (%)	0.60** ^b	0.57** ^b	0.43*	0.48*
RS Stage 3 (%)	0.62*** ^b	0.79*** ^a	0.74*** ^a	0.52*** ^b
HRR (%)	0.13	-0.01	0.21	0.37

Pearson's correlation, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. ^a very large correlation, ^b large correlation, ^c moderate correlation.

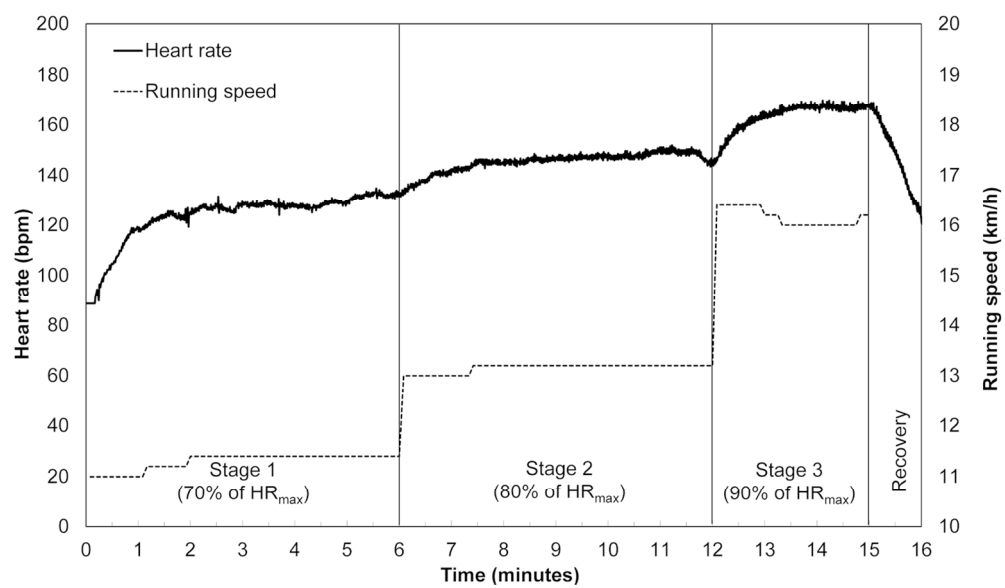
VO_{2max}, maximal oxygen consumption; RS_{peak}, peak running speed in the maximal treadmill test; RS at LT2, running speed at lactate threshold 2; RS at LT1, running speed at lactate threshold 1; RS, running speed; HRR, heart rate recovery.

Legends:

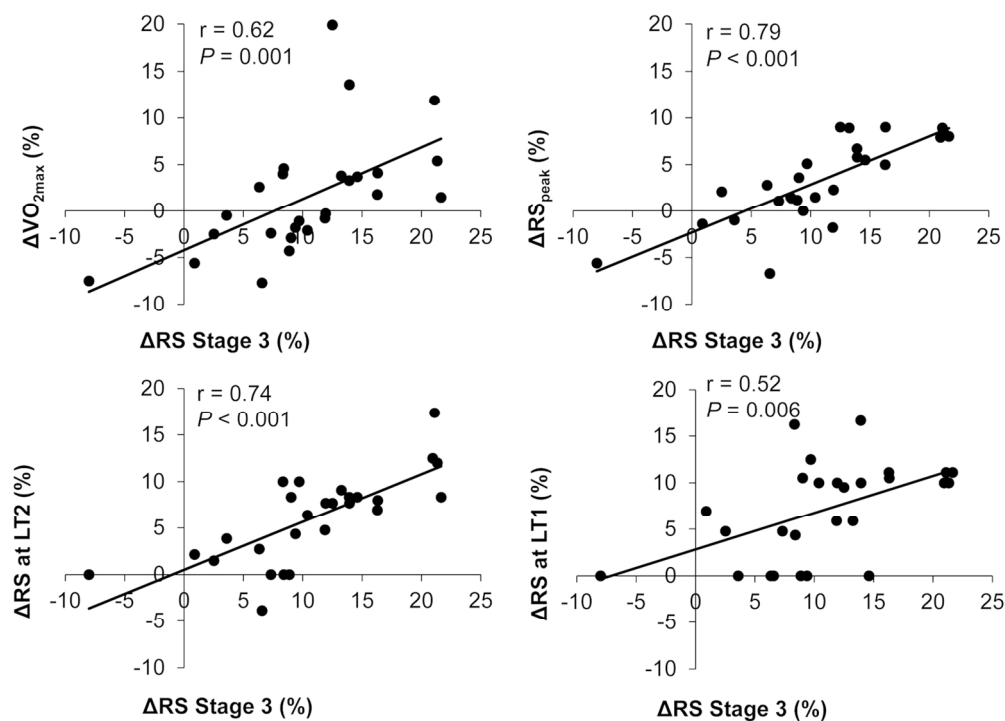
Figure 1 – An example of an arbitrary subject' training status test including heart rate and running speed during the submaximal running test.

Figure 2 – Correlations between the changes in endurance performance variables and the changes in running speed during the third stage in the submaximal running test (SRT, n = 26) after the 18 weeks of training. VO_{2max} , maximal oxygen consumption; RS_{peak} , peak running speed in the maximal treadmill test; RS at LT2, running speed at lactate threshold 2; RS at LT1, running speed at lactate threshold 1; RS Stage 3, running speed at 90% of HRmax in the submaximal running test.

Figure 3 – Representative time-series for the clusters based on the changes of running speed in the first (A), second (C), third stage (E) and heart rate recovery (G), and changes in peak running speed in the maximal treadmill test (RS_{peak}) for the clusters based on changes of RS 1 (B), RS 2 (D), RS 3 (F) and HRR (H). Between cluster differences in change of RS_{peak} : # $p < 0.05$, ## $p < 0.01$ (revealed by Kruskal-Wallis test).

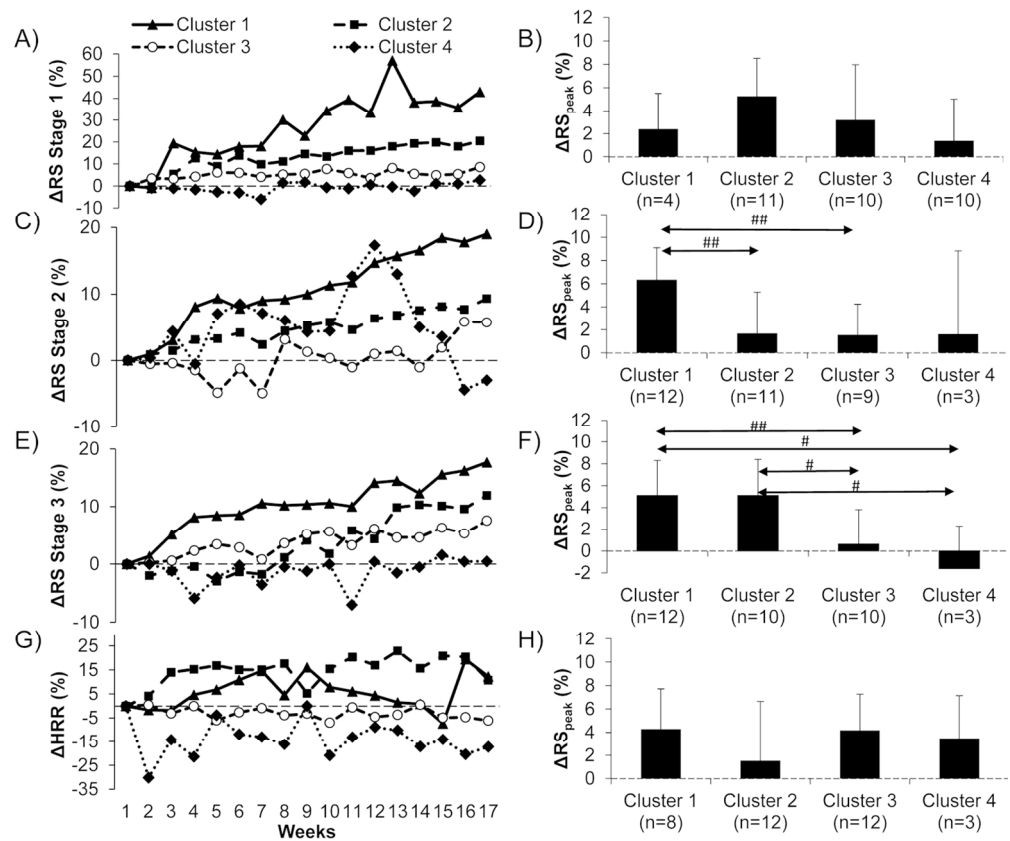


An example of an arbitrary subject' training status test including heart rate and running speed during the submaximal running test.
129x74mm (300 x 300 DPI)



Correlations between the changes in endurance performance variables and the changes in running speed during the third stage in the submaximal running test (SRT, $n = 26$) after the 18 weeks of training. VO_{2max} , maximal oxygen consumption; RS_{peak} , peak running speed in the maximal treadmill test; RS at LT2, running speed at lactate threshold 2; RS at LT1, running speed at lactate threshold 1; RS Stage 3, running speed at 90% of HRmax in the submaximal running test.

129x93mm (300 x 300 DPI)



Representative time-series for the clusters based on the changes of running speed in the first (A), second (C), third stage (E) and heart rate recovery (G), and changes in peak running speed in the maximal treadmill test (RS_{peak}) for the clusters based on changes of RS 1 (B), RS 2 (D), RS 3 (F) and HRR (H). Between cluster differences in change of RS_{peak} : # $p < 0.05$, ## $p < 0.01$ (revealed by Kruskal-Wallis test). 129x108mm (300 x 300 DPI)