ABSTRACT

Purpose: To examine the reproducibility and sensitivity of self-paced field running test (SFT) in monitoring of positive and negative changes in endurance performance.

Methods: A total of 27 (11 females) recreational runners participated in a 6-wk training intervention. The Intervention was divided into a 3-wk baseline period, a 2-wk overload period, and a 1-wk recovery period. An incremental treadmill test was performed before the baseline period, and a 3000-m running test before and after all periods (T1-T4). In addition, the participants performed once a week SFT (SFT1-6), which consisted of a submaximal (6+6+3-min test at perceived exertion of 9/20, 13/20, and 17/20) and maximal sections (6x3-min intervals at maximum sustainable effort). The associations between the incremental treadmill test and the SFT1 performance was examined with the Pearson correlation, and the intraclass correlation was analyzed for the parameters of SFT1-SFT3 sessions during the baseline period. The repeated measures correlation (RMC) was calculated for the 3000-m speed at T1-T4 and the corresponding speeds at SFT.

Results: Significant associations (r=0.68-0.93; $p<0.001$) were found between the speeds of SFT and the peak and lactate thresholds speeds of the incremental treadmill test. Intraclass correlations varied between 0.77-0.96 being the highest for the average speed of 6x3-min intervals. RMC was significant ($p<0.05$) for the 9/20 (r=0.24), 13/20 (r=0.24) and 6x3-min intervals (r=0.29).

Conclusions: The SFT seemed a reproducible method to estimate endurance performance in recreational runners. The sensitivity to track short-term and small magnitude changes in performance seems more limited and might require more standardized conditions.

Keywords: endurance training, running test, submaximal test, perceived exertion

INTRODUCTION

Endurance performance is strongly associated with maximum oxygen uptake, performance at lactate threshold, and exercise economy.[1] Furthermore, physiological resilience has been suggested to complete the main previously known predictors of endurance performance.[2] Since the assessment of these capabilities requires testing under laboratory conditions and specific equipment, feasible and minimally invasive testing methods are more regularly applied at field conditions.[3] Furthermore, to avoid disturbances in regular training process, these testing protocols are typically submaximal by nature.[3] As a typical example, a submaximal cycle test of Lamberts and Lambert consists of 6-min + 6-min + 3-min submaximal stages during which the corresponding heart rate (HR) is progressed from 60% to 80% to 90% of maximum.[4] Similar protocol has also been applied for running[5,6] and rowing[7]. The test results have been significantly associated with the endurance performance in all disciplines[4,5,7] supporting their usefulness in monitoring of training adaptations.

Although the internal-to-external-ratio, e.g. relative HR at a certain running speed[8] or cycling power[3], is a good indicator of endurance performance at cross-sectional assessments, the interpretation of the results can be more challenging in longitudinal settings. A decrease in HR at a certain external output is generally associated with positive training adaptations.[5,6] However, when preceded by significant increase in training load, it could also be indicative of functional overreaching[9], possibly due to the reduced secretion of adrenaline[10]. Therefore, it has been suggested that HR and external load should always be interpreted in conjunction with perceived effort.[3,9] Another challenge in HR-based tests is the fact that there can be a large discrepancy in the metabolic stress associated with the same relative intensity. At fixed HR-levels (e.g. 80%/max) this can lead individuals to be tested at different exercise intensity domains[8], which in most situations is not desirable.

Interestingly, it has been observed that rating of perceived exertion (RPE) at metabolic thresholds is estimated quite similarly across individuals.[11-13] This finding raises the question whether perceived exertion could be used as the primary regulator of pacing instead of HR or speed in the assessments of endurance performance. Sangan et al.[14] have previously reported the validity of a self-paced running test consisting of three (RPE 10, 13, and 17) 3-min stages. The authors concluded satisfactory validity and reliability, while the longitudinal alignment with the endurance performance remained unknown. Recently, Nuuttila et al.[15] examined the maximum sustainable effort intervals and found that changes in interval performance aligned well with the change in 3000-m and 10-km running performance. While self-paced tests could have potential in monitoring of endurance performance, it is unclear how sensitive self-paced tests are to training-induced fatigue (e.g. overreaching). Furthermore, it is currently unknown if maximal and submaximal self-paced field tests align similarly with the actual endurance performance.

The purpose of this study was to examine the reproducibility of a running test that was paced based on perceived effort at normal state of recovery. Secondly, the study aimed to investigate the sensitivity of submaximal and maximal self-paced tests to track negative and positive changes in 3000-m running performance during and after an overload period that was expected to induce overreaching in some individuals.

METHODS

Subjects

A total of 32 (18 males, 14 females) recreational runners were recruited for the study. With the Mckay classification framework[16], the participants could be classified as Tier 2. The health status of all individuals willing to participate was screened via a questionnaire to exclude any diseases or regular medications that could have affected the participation. In addition, their resting electrocardiography was recorded and approved by a physician before the final acceptance. In the current analyses, only participants who performed all prescribed testing sessions during the baseline period (n = 27) were included in the reproducibility analyses. In the longitudinal assessment, only participants who finished the whole study period were involved (n =24). All the participants gave their written consent to participate, and the study protocol was approved by the ethics committee of the University of Jyväskylä.

Design

The study consisted of three phases: a 3-week baseline training period (BL), a 2-week overload period (OL), and a 1-week recovery period (REC) (Figure 1). Each period was preceded/followed by a test day (T1-T4) during which maximal endurance performance was assessed with a 3000-m running test. In addition, a maximal incremental treadmill test was performed before BL. All tests were performed individually at the same time of the day (± 2 h) and preceded by a rest day. The self-paced field running test was performed as a control test once a week in field conditions (SFT1-6). The whole study protocol has been described in more detail at another publication.[17]

Methodology

Incremental treadmill test

An incremental treadmill test was performed before the baseline period to determine lactate thresholds and training zones. During the same visit, the participant's fat percentage was estimated with skinfold measurements.[18] The treadmill test started at the speed of 7 km/h (females) or 8 km/h (males), after which the treadmill speed was increased by 1 km/h every 3 minutes, and the test continued until volitional exhaustion. The incline was kept constant at 0.5 degrees. The treadmill was stopped between each stage for drawing blood samples from the fingertip for lactate analyses (Biosen S_line Lab+ lactate analyzer, EKF Diagnostic, Magdeburg, Germany). The HR (Polar H10, Polar Electro Oy, Kempele, Finland) and respiratory gases (Jaeger Vyntus CPX, CareFusion Germany 234 GmbH, Hoechberg, Germany) were also measured continuously during the test. The maximal oxygen uptake (VO_{2max}) was defined as the highest 60-s average of VO_2, and the maximum HR as the highest observed value during the test. The exercise economy was assessed as the last 60-s average of VO_2 (ml/kg/km) at 10 km/h. The maximal running speed of the test (vPeak) was defined as the highest speed in the last completed stage, or if the stage was not finished, as the speed of the last completed stage (km/h) + (running time (s) of the unfinished stage − 30 s)/(180 − 30 s) × 1 km/h. The first lactate threshold (LT1) and the second lactate threshold (LT2) were determined based on blood lactate changes during the test. The LT1 was set at 0.3 mmol/l above the lowest lactate value during the test. For the determination of LT2, two linear models were drawn: 1) between LT1 and the next measured lactate value and 2) for the lactate points which were preceded by a lactate increase of at least 0.8 mmol/l. LT2 was set at the intersection point between these two linear models. The treadmill and threshold assessment protocols were adopted from previous studies.[5,6,15]

3000-m running test

3000-m running tests were ran in small groups (max. 6 persons) in a 200-m indoor track (n = 18) or in a 400-m outdoor track (n = 6). The outdoor track was used for some participants due to the summer lockdown of the indoor track that was not known when the timetable of the data collection was designed. A standardized 15-min low-intensity warm-up including 3 x 20-30-s accelerations to the target speed was always performed before the test. The participants were given verbal encouragement and split times (1000 m and 2000 m) during the test.

Self-paced field running test

The self-paced field running test consisted of two sections: 1) RPE-based submaximal test 2) a 6x3-min maximal sustainable effort interval exercise. The whole protocol was instructed to be performed once a week on an even terrain, in the same or comparable environment and at the same time of day (± 2 h) within-individual. The submaximal test was developed from the RPE-based[14,19] and HR-based[5,6] running test applications of Lamberts and Lambert submaximal cycle test protocol[4]. The test involved two 6-min stages and one 3-min stage with intensities defined on the Finnish version of the 6-20 RPE scale[20] as 9 (very light), 13 (somewhat hard), and 17 (very hard). In the well-recovered state, these intensities were expected to correspond to approximately 70%, 80%, and 90% of the maximum HR. The average running speed and HR were calculated separately for each stage, but the first minute of each stage was excluded for allowing the adjustment of pace. The test was preceded and followed by a 1-min standing for the assessment of maximal rate of HR increase (rHRI)[21] at the beginning of the test, and 60-s HR recovery (HRR) after the test. Due to data quality related issues, rHRI-related results were available only for 20 individuals. The submaximal test is demonstrated in Figure 2.

After the submaximal test, the participants performed a 6x3-min interval exercise with 2-min active recovery at the maximum sustainable effort. The average running speed and the average HR were determined as the average of all intervals. The interval session was chosen as a part of the field running test, because it has previously been shown to strongly associate with the 3000-m running performance.[15]

The participants used an HR monitor (Polar Vantage V2) and a strap (Polar H10) in all tests. To help the proper execution of the self-paced field running test, a “favorite session” was created for the watch which took automatic split times for all stages and informed the runner when a new stage or interval started. All the test results were analyzed in the Polar Flow software, except for the rHRI which was analyzed with the Matlab software.

Statistical analysis

The results are presented as mean ± standard deviation. The reproducibility of the three first self-paced field running tests (SFT1-SFT3) was analyzed with the intra-class correlation coefficient

(ICC) and the coefficient of variation (CV). Pearson correlation coefficient was used to analyze associations between the first self-paced field running test during the baseline period (SFT1) and the preceding test results of the incremental treadmill test and 3000-m running test. To assess the sensitivity of the test to track potential negative and positive changes in 3000-m running performance across the study period, a repeated measures correlation[22] was analyzed for the T1/SFT1, T2/SFT3, T3/SFT5, and T4/SFT6 pairs. Similar analyses were also performed to assess the capability of the submaximal test parameters to predict the speed of the 6x3-min intervals at SFT1-6. Repeated measures correlation was calculated with the R studio (version 4.3.1) according to software and instructions provided by Marusich and Bakdash[23]. Other statistical analyses were performed with the IBM SPSS Statistics v.28 software (SPSS Inc., Chicago, IL).

RESULTS

Baseline characteristics of the participants are presented in Table 1.

Reproducibility of self-paced field running test

The ICC and CV for the parameters of the self-paced field running test are presented in Table 2. All reported correlations were significant ($p < 0.05$). The ICC of running speed and HR was greater than 0.70 in all stages, and the CV for all parameters was ≤ 5.0%, except for rHRI and HRR.

Associations between the incremental treadmill test performance and self-paced field running test

The Pearson correlation coefficients for the self-paced field running test parameters and incremental treadmill test parameters are presented in Table 3. All field test results of the studied parameters correlated significantly with the treadmill test results of the studied parameters, except for running economy.

The running speeds of the RPE9, RPE13 and RPE17, and 6x3-min intervals were at SFT1 57.6 ± 6.2%/vPeak, 71.5 ± 7.9%/vPeak, 87.3 ± 7.1%/vPeak, and 92.4 ± 4.6%/vPeak. In turn, the corresponding HR for the RPE9, RPE13, RPE17, and 6x3-min intervals was 66.6 ± 5.8%/HRmax, 76.9 ± 5.8%/HRmax, 87.6 ± 3.8%/HRmax, and 87.2 ± 2.8%/HRmax. The submaximal running speeds (SFT1-3) in relation to lactate thresholds and vPeak are demonstrated individually in Figure 3. Speed of the RPE9 at SFT1 was on average below the LT1 (88.0 ± 8.5 %/vLT1), while the running speed of the RPE 13 was between the LT1 and LT2 (109.2%/vLT1 and 89.1 ± 9.2%/vLT2). The running speeds of the RPE 17 and 6x3-min were above the LT2 (108.9 ± 9.1%/vLT2 and 115.3 ± 6.1%/vLT2).

Self-paced field running test in longitudinal monitoring of fatigue and training adaptations

3000-m running speed increased ($p < 0.001$) from T1 (14.0 ± 2.1 km/h) to T4 (14.6 ± 2.2 km/h). In turn, the running speed did not change at any RPE-stage from SFT1 to SFT6, but the speed of the 6x3-min session increased ($p = 0.02$) from 14.2 ± 2.0 km/h to 14.5 ± 2.0 km/h. The HR-RS index increased from SFT1 to SFT6 at all RPE-stages ($p < 0.05$) and during the 6x3-min session ($p < 0.001$).

Repeated measures correlations between the 3000-m running speed and different speeds of the self-paced field running test are presented in Table 4. Correlations were significant ($p < 0.05$) for the running speeds and HR-RS index of all stages apart from the speed of RPE17. Figure 4 demonstrates individual examples of large positive within-participant correlations and negative within-participant correlations between the 3000-m running speed and 6x3-min running speed. Repeated measures correlations for the 6x3-min running speed and parameters of the submaximal test are also presented in Table 4. Among the field test parameters, the running speed of the RPE17 was most strongly associated with the 6x3-min running performance ($r = 0.44$, $p < 0.001$).

DISCUSSION

The main findings of the present study were: 1) The self-paced field running test was significantly associated with the incremental treadmill test performance. 2) Based on ICC and CV, the Speed and HR of the self-paced field running test were reproducible makers, while rHRI and HRR seemed more variable. 3) The self-paced field running test might not be sensitive in tracking short-term and/or small magnitude changes in running performance of recreational runners.

ICC for the running speeds varied between 0.77 (RPE13) and 0.96 (6x3-min). In turn, intraclass correlations were slightly smaller for HR, varying between 0.73 (RPE13) and 0.85 (6x3-min). Previously, Sangan et al.[14] have examined the reproducibility of the self-paced running test with a similar setting and reported very comparable ICC results for running speeds (0.76-0.83) and HR (0.72-0.92). Although O'Grady et. al.[19] have suggested that longer stages (e.g., 1-min or 4-min vs. 8-min stages) would result in the greatest consistency on within- and between-athlete responses, the difference seemed negligible between the current 6-min and Sangan et al.[14] 3-min stages. Regarding the effect of duration, one important aspect is that perceived exertion at given speed/power increases over time, even at low intensities.[24] O'Grady et al.[19] also reported that at RPE 17, the cycling power output was decreased significantly between durations of 1 minute, 4 minutes and 8 minutes. Thus, the ratio between perceived exertion and external output is not locked but rather scaled based on the duration that certain intensity must be sustained.

The speed of all RPE-stages and 6x3-min intervals correlated ($r = 0.68$-0.93) with the threshold and maximum performance of the incremental treadmill test. The present results are in line with the HR-based field application of a similar test[5], and associations were slightly greater compared with the results of Sangan et al.[14]. Although the reproducibility did not differ between 3-min[14] and current 6-min stages, it is possible that the validity was positively affected by the longer stage durations. Many previous studies have reported that RPE values at physiological thresholds are estimated quite similarly across individuals during the incremental test.[11-13] Giovanelli et al.[25] have also suggested that the RPE-based RABIT test, which consists of four self-paced stages, might be used for detecting training zones in athletes. In the current tests, different RPE-stages seemed to be located quite similarly in relation to thresholds across individuals, thus supporting the potential of self-paced running tests as a method for non-invasive threshold assessments. Neither RPE9, RPE13 nor RPE17 were located exactly at the threshold levels, but hypothetically RPE11 could be the best match for the vLT1 and RPE15 for the vLT2. There were also some exceptions regarding the associations between thresholds and self-paced test speeds, but these outliers could also relate to error sources of the treadmill test, taking into account the variation that occurs from day to day even in laboratory conditions[26].

Although the reliability and validity of the test are important factors, also the sensitivity of the test to respond is critical, when it is used in regular monitoring.[27] Test results should align with positive long-term training adaptations, but they should also be able to indicate negative and short-term changes in performance. It has been reported already in the early 1970s that perceived exertion at given workload decreases after physical training but remains the same compared to relative values.[28] Up to this point, no studies have reported the sensitivity of a self-paced exercise test to track positive and negative changes in endurance performance during and after training intervention, emphasizing the unique approach of the present study. Interestingly, repeated measures correlations were relatively small, and the self-paced running test did not seem very sensitive in tracking small-magnitude or short-term changes in 3000-m running performance. Previously, changes in 6x3-min maximum sustainable effort interval performance have correlated with the changes in 3000-m and 10-km running performance.[15] However, the current study setting with an overload period was somewhat different, and fewer interval sessions were performed compared with Nuuttila et al. study[15]. Therefore, it is possible that a "learning effect" affects positively the sensitivity of the self-paced running test, and more thorough familiarization should be performed to improve the accuracy of the test.

The sensitivity of a test is always affected by the signal-to-noise-ratio: what is the expected magnitude of change compared to the noise of the test.[29] The coefficient of variation in the self-paced running test varied between 2.2 and 5.0%, and it is plausible that the reproducibility of RPE-stages was too low for detecting small-magnitude changes in performance (e.g. 1-3%). It is also possible that the overload period affected differently self-paced sessions vs. supervised test sessions. For example, the verbal encouragement during exercise testing can have a significant effect on performance[30], and it can be hypothesized that performing maximum sustainable effort intervals unsupervised might, in some cases, lead to submaximal efforts. This was supported by the fact that repeated measures correlations were greater for the HR-RS index which takes into account the relation between HR and running speed. It must also be acknowledged that the level of expertise can affect the processes related to pacing.[31] As can be seen from the Figure 4, there were individuals whose interval performance and 3000-m performance aligned very well, while in some individuals the relationship was even negative. Therefore, it could be concluded that the sensitivity of self-paced running tests varies between individuals.

It is important to notice that the self-paced field running tests were not performed immediately before the 3000-m running test. Since the participants were advised to perform the test based on the current perceptions, they could have differed from the perceptions of the test day. On the other hand, when the associations between the submaximal RPE-stages and same-session 6x3-min interval performance were assessed with the repeated measures correlations, the results seemed to be surprisingly poorly aligned. As expected, the greatest correlation was found for RPE17, but despite the speed being very close to the 6x3-min speed, the correlation remained below 0.50. This demonstrates well how the perception during (submaximal) warm-up is not a very accurate indicator of the current maximum performance. An interesting nuance, regarding this phenomenon, is that effort (e.g., maximum sustainable effort) and exertion (e.g., RPE) could be regarded as slightly different constructs, and the neural processes involved in the development of perceived effort and exertion can differ.[32] Thus, it can be expected that the results are not exactly similar.

Besides the running speeds, also rHRI and HRR were monitored during the field tests. The baseline associations found between treadmill test parameters and HR-kinetics confirmed that they relate to endurance performance, and these results are in line with studies reporting correlations with HRR or rHRI and exercise performance.[21,33] On the other hand, based on the reproducibility of the parameters, it seems that a more standardized starting speed and finishing HR would be required for monitoring purposes. Previous literature has suggested these markers to be useful in the monitoring of training status, but there are also some contradictory findings.[8] Especially, the rHRI-parameter would require reliability assessments in more standardized conditions and in different populations, because it has been proposed that fitness level can also affect the sensitivity of the marker.[21]

Limitations: The self-paced running tests were performed in field conditions, and external factors, such as running terrain, temperature, or humidity, have varied within and between individuals. On the other hand, current conditions were estimated to simulate the actual testing and training conditions of recreational runners. More standardized conditions would have most likely affected the reproducibility and sensitivity of the results positively. Maximal running performance was assessed only with the 3000-m test; thus, it is not clear how changes in thresholds or other physiological parameters would translate into the field test performance. Finally, the current study population consisted of recreational runners, and the results cannot be extrapolated uncritically to untrained or well-trained individuals.

Practical Applications

The current study demonstrated that a self-paced field running test can be a feasible and reproducible option for the assessment of endurance performance in recreational runners. Different submaximal RPE stages aligned quite similarly in relation to physiological thresholds across participants, and based on associations with the treadmill test performance, self-paced running tests could potentially be used as an indirect estimation of thresholds. This study did not support the sensitivity of the self-paced field running test to detect small-magnitude variations in running performance, but further studies are needed to gain more insights from different populations and more standardized testing conditions.

Conclusions

The present self-paced field running test that was regulated based on perceived exertion/effort was a reproducible method to estimate endurance performance in recreational runners. The sensitivity to track short-term and small magnitude changes in running performance seems to be more limited and might require more standardized conditions or more thorough familiarization with the test.

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REFERENCES

1. Bassett DR Jr, Howley ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. Med Sci Sports Exerc. 2000;32(1):70-84.
2. Jones AM. The fourth dimension: physiological resilience as an independent determinant of endurance exercise performance. J Physiol. Published online August 22, 2023
3. Capostagno B, Lambert MI, Lamberts RP. A Systematic Review of Submaximal Cycle Tests to Predict, Monitor, and Optimize Cycling Performance. Int J Sports Physiol Perform. 2016;11(6):707-714.
4. Lamberts RP, Swart J, Noakes TD, Lambert MI. A novel submaximal cycle test to monitor fatigue and predict cycling performance. Br J Sports Med. 2011;45(10):797-804.
5. Vesterinen V, Nummela A, Ayramo S, et al. Monitoring Training Adaptation With a Submaximal Running Test Under Field Conditions. Int J Sports Physiol Perform. 2016;11(3):393-399.
6. Vesterinen V, Nummela A, Laine T, Hynynen E, Mikkola J, Häkkinen K. A Submaximal Running Test With Postexercise Cardiac Autonomic and Neuromuscular Function in Monitoring Endurance Training Adaptation. J Strength Cond Res. 2017;31(1):233-243.
7. Otter RT, Brink MS, Lamberts RP, Lemmink KA. A New Submaximal Rowing Test to Predict 2,000-m Rowing Ergometer Performance. J Strength Cond Res. 2015;29(9):2426-2433.
8. Schimpchen J, Correia PF, Meyer T. Minimally Invasive Ways to Monitor Changes in Cardiocirculatory Fitness in Running-based Sports: A Systematic Review. Int J Sports Med. 2023;44(2):95-107
9. Roete AJ, Elferink-Gemser MT, Otter RTA, Stoter IK, Lamberts RP. A Systematic Review on Markers of Functional Overreaching in Endurance Athletes. Int J Sports Physiol Perform. 2021;16(8):1065–1073.
10. Le Meur Y, Louis J, Aubry A, Guéneron J, Pichon A, Schaal K, Corcuff JB, Hatem SN, Isnard R, Hausswirth C. Maximal exercise limitation in functionally overreached triathletes: role of cardiac adrenergic stimulation. J Appl Physiol (1985). 2014;117(3):214-222.
11. Fabre N, Mourot L, Zerbini L, Pellegrini B, Bortolan L, Schena F. A novel approach for lactate threshold assessment based on rating of perceived exertion. Int J Sports Physiol Perform. 2013;8(3):263-270.

12. Scherr J, Wolfarth B, Christle JW, Pressler A, Wagenpfeil S, Halle M. Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. Eur J Appl Physiol. 2013;113(1):147-155.
13. Dantas JL, Doria C, Rossi H, et al. Determination of blood lactate training zone boundaries with rating of perceived exertion in runners. J Strength Cond Res. 2015;29(2):315-320.
14. Sangan HF, Hopker JG, Davison G, McLaren SJ. The Self-Paced Submaximal Run Test: Associations With the Graded Exercise Test and Reliability. Int J Sports Physiol Perform. 2021;16(12):1865-1873.
15. Nuuttila OP, Matomäki P, Kyröläinen H, Nummela A. Predicting Running Performance and Adaptations from Intervals at Maximal Sustainable Effort. Int J Sports Med. 2023;44(9):657-663.
16. McKay AKA, Stellingwerff T, Smith ES, et al. Defining Training and Performance Caliber: A Participant Classification Framework. Int J Sports Physiol Perform. 2022;17(2):317-331.
17. Nuuttila O-P, Uusitalo A, Kokkonen V-P, Weerarathna N, Kyröläinen H. Monitoring fatigue state with heart rate-based and subjective methods during intensified training in recreational runners. Eur J Sport Sci. 2024. Early view. https://doi.org/10.1002/ejsc.12115
18. Durnin JV, Rahaman MM. The assessment of the amount of fat in the human body from measurements of skinfold thickness. Br J Nutr. 1967;21(3):681-689.
19. O'Grady C, Passfield L, Hopker JG. Variability in Submaximal Self-Paced Exercise Bouts of Different Intensity and Duration. Int J Sports Physiol Perform. 2021;16(12):1824-1833.
20. Keskinen, K. L., Häkkinen, K., & Kallinen, M. (Eds.). (2018). Fyysisen kunnon mittaaminen: käsi-ja oppikirja kuntotestaajille. Liikuntatieteellisen Seuran.
21. Bellenger CR, Thomson RL, Davison K, et al. Optimization of Maximal Rate of Heart Rate Increase Assessment in Runners. Res Q Exerc Sport. 2018;89(3):322-331.
22. Bakdash JZ, Marusich LR. Repeated Measures Correlation. Front Psychol. 2017;8:456.
23. Marusich LR, Bakdash JZ. rmcorrShiny: A web and standalone application for repeated measures correlation. F1000Res. 2021;10:697.
24. Matomäki P, Heinonen OJ, Nummela A, et al. Durability is improved by both low and high intensity endurance training. Front Physiol. 2023;14:1128111.
25. Giovanelli N, Scaini S, Billat V, Lazzer S. A new field test to estimate the aerobic and anaerobic thresholds and maximum parameters. Eur J Sport Sci. 2020;20(4):437-443.
26. Zinner C, Gerspitzer A, Düking P, et al. The magnitude and time-course of physiological responses to 9 weeks of incremental ramp testing. Scand J Med Sci Sports. 2023;33(7):1146-1156.
27. Currell K, Jeukendrup AE. Validity, reliability and sensitivity of measures of sporting performance. *Sports Med*. 2008;38(4):297-316
28. Ekblom, B., & Golobarg, A. N. (1971). The influence of physical training and other factors on the subjective rating of perceived exertion. Acta Physiologica Scandinavica, 83(3), 399-406.
29. Buchheit M. Monitoring training status with HR measures: do all roads lead to Rome?. Front Physiol. 2014;5:73.

30. Midgley AW, Marchant DC, Levy AR. A call to action towards an evidence-based approach to using verbal encouragement during maximal exercise testing. Clin Physiol Funct Imaging. 2018;38(4):547-553.
31. Holgado D, Sanabria D. Does self-paced exercise depend on executive processing? A narrative review of the current evidence. IRSEP. 2021;14:(1):130-153.
32. Abbiss CR, Peiffer JJ, Meeusen R, Skorski S. Role of Ratings of Perceived Exertion during Self-Paced Exercise: What are We Actually Measuring?. *Sports Med*. 2015;45(9):1235-1243
33. Lamberts RP, van Erp T, Javaloyes A, Eken MM, Langerak NG, Tam N. Reliability of recovery heart rate variability measurements as part of the Lamberts Submaximal Cycle Test and the relationship with training status in trained to elite cyclists. Eur J Appl Physiol. Published online January 10, 2024.

FIGURE CAPTIONS

Figure 1. Study design. SFT1-6 refers to self-paced field running tests and T1-T4 to 3000-m running test days. An incremental treadmill test was performed during the preceding week of the baseline period. The training load was defined as Lucia's TRIMP.

Figure 2. An example of the execution of the submaximal test in a self-paced field running test. HRR = heart rate recovery; rHRI = maximal rate of heart rate increase; RPE = rating of perceived exertion.

Figure 3. Running speed in relation to the individual's first lactate threshold (lowest line), second lactate threshold (middle line), and peak speed of the incremental treadmill test (highest line)

during the three first three submaximal tests (SFT1-3). Each individual's results are presented vertically.

Figure 4. All individuals (A) and examples of individuals with good (B) and poor (C) agreement between changes in 3000-m and 6x3-min running performance. Data points of each individual are marked with the same color.