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ASSESSING OVERREACHING WITH HRR: WHAT IS THE MINIMAL EXERCISE INTENSITY REQUIRED?

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ABSTRACT

Purpose: Faster heart rate recovery (HRR) following high-to-maximal exercise (≥90% HRmax) has been reported in athletes suspected of functional overreaching (f-OR). This study investigated whether this response would also occur at lower exercise intensity. **Methods and Results:** HRR and rate of perceived exertion (RPE) responses were compared during an incremental intermittent running protocol to exhaustion in twenty experienced male triathletes (8 control and 13 overload subjects led to f-OR) before (Pre), immediately after an overload training period (Mid) and following a 1-week taper (Post). Both groups demonstrated an increase in HRR values at Mid, but this change was *very likely* to *almost certainly larger* in the f-OR group at all running intensities (*large* to *very large* differences, e.g. +16 ±7 bpm vs. +3 ±5 bpm, in the f-OR and control groups at 11 $km{\cdot}h^{-1}$, respectively). The highest between-group differences in changes in HRR were reported at 11 $km{\cdot}h^{-1}$ (13 ±4 bpm) and 12 $km{\cdot}h^{-1}$ (10 ±6 bpm). A concomitant increase in RPE at all intensities was reported only in the f-OR group (*large-to-extremely large* differences, +2.1 ±1.5 to +0.7 ±1.5 AU). **Conclusion:** These findings confirm that faster HRR does not systematically predict better physical performance. However, when interpreted in the context of the athletes' fatigue state and training phase, HRR following submaximal exercise may be more discriminant than HRR measures taken following maximal exercise for monitoring f-OR. These findings may be applied in practice by regularly assessing HRR following submaximal exercise (i.e., warm-up) for monitoring endurance athletes responses to training.

Keywords: fatigue, overtraining, heart rate, cardiac response, endurance training

INTRODUCTION

In many endurance sports, the competitive season involves a series of events that stretch over several weeks or months (e.g. cycling, triathlon, biathlon). In this context, regular peaking for major competitions (e.g. each month, every other week etc.) often poses the problem for coaches and athletes in deciding whether they should focus training toward developing fitness (i.e. overload training) between events, or to reduce training loads between events to optimize recovery. Whilst both approaches may be appropriate for different athletes at different times, these decisions should be informed by the athletes current training status and the period between events and the relative importance of each event. Regardless of the strategy employed, it is often impractical to follow best practise recommendations for taper periods (i.e. large training volume reduction (~50%) over a prolonged period (~1 or 2 weeks) when competitions are close together) as this may lead to detraining. Conversely, the combination of frequent competitions interspersed with short tapers increases the risk of persistent fatigue.[1] Indeed, when the balance between appropriate training stress and adequate recovery is disrupted, an abnormal training response may occur, inducing short-term "overreaching" (functional OR, f-OR)[1] which results in a decline in performance. Whilst f-OR is generally reversed after a short recovery period (~1-2 weeks),[1] it can compromise the immediate competition performance. Even if recent researches have shown that training diaries with subjective response may provide useful "warning signals" to both athletes and coaches during overload training/competitive periods [2, 3], the currently accepted method for diagnosing f-OR is to monitor performance after completion of a resting period of several days or weeks.[4] Unfortunately, this retrospective method of diagnosis is often rejected by coaches and athletes because it may disrupt the planned training and result in detraining. It is therefore important to identify early markers of f-OR for endurance athletes who require large training loads to achieve peak performance.

Among the myriad of markers reported to be suitable for monitoring training, heart rate recovery (HRR) has been suggested to be a promising non-invasive objective measure that can be used to identify if an athlete is adapting to training.[5, 6] Several studies have shown a faster HRR following high-intensity exercise in endurance athletes suspected of f-OR,[7-9] suggesting that this parameter is sensitive to the development of f-OR. However, this response has only been reported after high-to-maximal exercise bouts (i.e. ≥90% HRmax).[7-9] From a practical stand point, the requirement for near-maximal or maximal exercises may limit its wider application as a monitoring tool for endurance athletes as it is likely that a coach would be hesitant to implement an intense exercise bout to detect OR in already fatigued athletes, as it may further exacerbate this condition. Therefore, if HRR following lower or moderate-intensity exercise was to respond in a similar manner than after high-intensity exercise, it may be more suitable to monitor training responses. Therefore, to assess the value of HRR following sub-maximal exercise to assess f-OR, we re-visited known data sets describing the

HR(R) response of triathletes developing f-OR during a 3-week overload training block.[10] The intermittent discontinuous running test used before and after the development of OR allowed repeated HRR measures across a large exercise intensity spectrum (~60%–100% of maximal aerobic speed [MAS]).

MATERIAL AND METHODS

Participants and Training Intervention. Twenty well-trained triathletes (age 32 ± 8 y, VO_{2max} 62 ± 3 mL $O_2.min^{-1}.kg^{-1}$, and estimated maximum aerobic speed 18.2 ± 1.1 km/h) were assigned to either an overload training (n = 13) or control group (n = 8). The trained triathletes underwent a 5-week training intervention consisting of 1 week of a baseline phase (50% of their normal training load) and 3 weeks of habitual (control group) or overload training (40% increase in training load), followed by a 1-week taper (same as baseline training) and has been described in detail elsewhere.[10]

Performance Test. At the end of each training phase, the participants performed an discontinuous incremental running test to volitional exhaustion (starting at 11 $km.h^{-1}$ for 3 min and increasing speed by 1 $km.h^{-1}$ every 3 min thereafter) on a 340-m running track. A passive rest period of 1-min was provided between each running step. Running performance was defined as the total distance covered during the test until exhaustion.

HRR. Heart rate values were monitored every second using a HR monitor (RS800sd, Polar Electro, Kempele, Finland) and subsequently averaged every 5 s. HRR was assessed during the 1-min recovery period occurring at the end of each running step test and reported as the difference between the HR at cessation of exercise and the HR recorded at the end of the recovery period (i.e. 60 s after).[11]

RPE. The rating of perceived exertion (RPE) was provided verbally using the 6–20 Borg scale immediately at the end of running step and at exercise cessation.[12]

Statistical analysis

Data were assessed for practical significance using magnitude-based inferences.[13] All data were log-transformed prior to analysis to reduce bias arising from non-uniformity of error. To compare within-trial changes between trials, we used a modified statistical spreadsheet.[14] This spreadsheet calculates the between-trial standardised differences or effect sizes (ES, 90 % confidence interval [CI]) using the pooled standard deviation. Threshold values for ES statistics were ≤ 0.2 (*trivial*), >0.2 (*small*), >0.6 (*moderate*), >1.2 (*large*), >2.0 (*very large*), and >4.0 (*extremely large*). In addition, we calculated probabilities to establish whether the true (unknown) differences were lower, similar or higher than the smallest worthwhile change or difference (i.e. ES ≤ 0.2, trivial). Quantitative chances of higher or lower differences were evaluated qualitatively as follows: <1%, *almost certainly not*; 1-5%, *very unlikely*; 5-25%, *unlikely*; 25-75%, *possible*; 75-95%, *likely*; 95-99%, *very likely*; >99%, *almost certain*. If the chance of higher or lower differences was >5%, the true difference was assessed as *unclear*. Otherwise, we interpreted that change as the observed chance. Data in text and figures are presented as mean ±90% CI.

RESULTS

Performance. At the end of the overload period, running performance was *almost certainly* decreased in the intensified training group compared with its Pre value (-9.0 ±2.0% of Pre value). When associated with a higher perceived fatigue at rest, this performance decrement was followed by an *almost certain large* performance supercompensation during the taper, characterizing a state of functional overreaching (f-OR).[1] Within-group changes in performance in the control group were *likely trivial* during the same periods.

HRR. The control group demonstrated a *likely-to-very likely* faster HRR at all exercise intensities at Mid and Post versus Pre (*moderate*, mean increase from +3 ±5 to +6 ±8 bpm, Figure 1). An *almost certain* increase in HRR was observed at Mid versus Pre at all exercise intensities in the f-OR group (very large-to-extremely large, mean increase from +9 ±8 to +16 ±7 bpm, Figure 1), with greater increases at 11 $km.h^{-1}$ (+16 ±7 bpm) and 12 $km.h^{-1}$ (+14 ±10 bpm). Between-group differences in change from Pre to Mid were *very likely-to-almost certainly larger* in the f-OR group at all running intensities (*large to very large* differences, mean difference in change from -13 ±4 to -6 ±6 bpm).

RPE. Within-group changes in RPE from Pre were *unclear* in the control group at Mid and Post at all intensities. The f-OR group demonstrated a *likely-to-almost certain* increase in RPE at all running speeds during the overload period versus Pre (*very large-to-extremely large* increases, mean decrease from +1.1 ±0.9 to +1.9 ±2.1 AU). The between-group differences in change was systematically *likely to very likely* substantial between Pre and Mid (*large-to-extremely large* differences, +2.1 ±1.5 to +0.7 ±1.5 AU).

DISCUSSION

This study demonstrates that the faster HRR associated with f-OR in trained endurance athletes can be observed over a wide range of exercise intensities (~60-100% of MAS). More specifically, we observed that the magnitude of the acceleration of HRR with f-OR was the greatest at the lowest intensities (~60-65% of MAS).

Although previous studies have shown that a faster HRR may be indicative of an enhanced training status,[6] the present results confirm that this may not always occur. The present findings show that a faster HRR following a standardized submaximal test (e.g. a warm-up) combined with a higher RPE may be a practical early marker of f-OR in endurance athletes. In fact, the greater HRR change in response to f-OR after submaximal bouts may compensate for the slightly lower reliability of HRR after lower intensity bouts.[15, 16] The increased HRR response at lower intensities likely leads to a greater signal-to-noise ratio and, in turn, to an improved sensitivity compared to the HRR response following higher intensity bouts. This new approach for detecting f-OR is likely to be attractive to coaches and athletes as it is a relatively non-invasive measure and fulfills the suggested criteria for a suitable marker for detecting f-OR[17] [i.e. s 1) objective; 2) not easily manipulated; 3) applicable in training practice; 4) not too demanding for athletes; 5) affordable for the majority of athletes; and, 6) based on a theoretical framework]. As further evidence of the suitability of this approach for monitoring endurance training, HRR returned to its baseline value at the end of the taper phase, when the signs of f-OR had dissipated. These observations further demonstrate the sensitivity of HRR to changes athletes training states.

Because the control group revealed a likely increase in HRR during the training period in the absence of any signs of f-OR (i.e., low perceived fatigue at rest, no increase in RPE and unaltered performance), the present results show also that HRR should always be interpreted in the context of the specific training phase while considering the magnitude of HRR change and the perceptual response to training (i.e. perceived fatigue at rest and RPE). A faster HRR may only reflect a positive response to training, when it is associated with low-to-moderate level of perceived fatigue and decrease in RPE at a given submaximal exercise intensity. In contrast, a large increase in HRR during an overload training period coupled with high perceived fatigue at rest and a higher RPE during a standardized warm-up may in contrast suggest the development of f-OR. Whilst the value of the combined HR and RPE responses for monitoring training adaptations in soccer players has already been confirmed by Buchheit et al.[18]; the present study is the first to assess the usefulness of this approach with f-OR endurance athletes. The current results reinforce the necessity to systematically associate HR monitoring variables with perceptual measures during submaximal testing to limit the risk of misinterpretation, and confirms that a mixed-methods approach to monitoring should include both subjective and objective measures.[1] This integrated approach may be the optimal method for tracking athletes responses to training and indentifying signs of OR in endurance athletes (see typical example in Figure 2).[19]

The faster HRR reported at all exercise intensities in the control group was not associated with any clear change in maximal HR at exhaustion (+1 ± 1 bpm, *trivial*). This response suggests a change in the autonomic modulation during the immediate post-exercise recovery period (i.e. larger parasympathetic reactivation and/or sympathetic withdrawal) but not during exercise in this group. In contrast, increased HRR values were associated with an *almost certain* reduced maximal HR in the f-OR group (-9 ± 4 bpm, *moderate*). This finding suggests a downregulation of the sympathetic nervous system and/or an increased parasympathetic activity both at exercise and during the immediate post-exercise recovery phase. Unfortunately, because we did not determine any further specific markers, the contribution of these different mechanisms to the outcome (i.e. maximal HR, HRR) cannot be defined and any interpretation would be speculative. Nevertheless, since the parasympathetic nervous system activity is progressively reduced during an incremental exercise,[20] the progressive reduction in HRR acceleration reported with exercise intensity may indicate an increased vagal activity in the f-OR group at the end of the overload period. Without excluding the possibility of a reduced catecholaminergic response to intense exercise, this assumption is in line with previous investigators[21] [10], who have reported a progressive increase in the parasympathetic activity of resting HR in endurance athletes with f-OR. Further investigations involving autonomic blockades are required to test this hypothesis.

CONCLUSION

The present findings provide new information demonstrating a faster HRR after a wide of exercise intensities (~60–100% of MAS) in trained triathletes who developed f-OR during an overload training program. This finding confirms that faster HRR does not systematically predict better physical performance and demonstrates that when interpreted in the context of the athletes' fatigue state and training phase, HRR may be a practical tool for monitoring the response to training, without requiring to complete a training session at maximal intensity.

PRACTICAL IMPLICATIONS

- Endurance athletes should reproduce a standardized warm-up routine regularly (e.g. weekly during intensified training periods) to track changes in HR, HRR and RPE changes at a given sub-maximal intensity in order to track the response to training.
- A faster HRR does not systematically predict better physical performance.
- The interpretation of HRR should always be made in relation to the specific training phase of an endurance training program and the perceptual response to training (i.e. perceived fatigue at rest or RPE).
- A faster HRR and an increased RPE at submaximal intensity (~60 % of MAS) associated with a high perceived fatigue at rest may be an early sign of functional overreaching.

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REFERENCES

1. Meeusen R, Duclos M, Foster C, Fry A, Gleeson M, Nieman D, Raglin J, Rietjens G, Steinacker J, Urhausen A, European College of Sport S, American College of Sports M. Prevention, diagnosis, and treatment of the overtraining syndrome: joint consensus statement of the European College of Sport Science and the American College of Sports Medicine. *Med Sci Sports Exerc*. 2013;45:186-205.
2. Decroix L, Piacentini MF, Rietjens G, Meeusen R. Monitoring Physical and Cognitive Overload During a Training Camp in Professional Female Cyclists. *Int J Sports Physiol Perform*. 2016.
3. Piacentini MF, Meeusen R. An online training-monitoring system to prevent nonfunctional overreaching. *Int J Sports Physiol Perform*. 2015;10:524-7.
4. Halson SL, Jeukendrup AE. Does overtraining exist? An analysis of overreaching and overtraining research. *Sports Med*. 2004;34:967-81.
5. Buchheit M. Monitoring training status with HR measures: do all roads lead to Rome? *Front Physiol*. 2014;5:73.
6. Daanen HA, Lamberts RP, Kallen VL, Jin A, Van Meeteren NL. A systematic review on heart-rate recovery to monitor changes in training status in athletes. *Int J Sports Physiol Perform*. 2012;7:251-60.
7. Lamberts RP, Rietjens GJ, Tijdink HH, Noakes TD, Lambert MI. Measuring submaximal performance parameters to monitor fatigue and predict cycling performance: a case study of a world-class cyclo-cross cyclist. *Eur J Appl Physiol*. 2010;108:183-90.
8. Dupuy O, Bherer L, Audiffren M, Bosquet L. Night and postexercise cardiac autonomic control in functional overreaching. *Appl Physiol Nutr Metab*. 2013;38:200-8.
9. Thomson RL, Bellenger CR, Howe PR, Karavirta L, Buckley JD. Improved heart rate recovery despite reduced exercise performance following heavy training: A within-subject analysis. *J Sci Med Sport*. 2016;19:255-9.
10. Le Meur Y, Pichon A, Schaal K, Schmitt L, Louis J, Gueneron J, Vidal PP, Hausswirth C. Evidence of parasympathetic hyperactivity in functionally overreached athletes. *Med Sci Sports Exerc*. 2013;45:2061-71.
11. Dupuy O, Mekary S, Berryman N, Bherer L, Audiffren M, Bosquet L. Reliability of heart rate measures used to assess post-exercise parasympathetic reactivation. *Clin Physiol Funct Imaging*. 2012;32:296-304.
12. Borg G. Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med*. 1970;2:92-8.
13. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*. 2009;41:3-13.
14. Hopkins WG. Spreadsheets for analysis of controlled trials with adjustment for a subject characteristic. *Sportscience*. 2006;10:46-50.
15. Lamberts RP, Maskell S, Borresen J, Lambert MI. Adapting workload improves the measurement of heart rate recovery. *Int J Sports Med*. 2011;32:698-702.
16. Bosquet L, Gamelin FX, Berthoin S. Reliability of postexercise heart rate recovery. *Int J Sports Med*. 2008;29:238-43.
17. Nederhof E, Lemmink KA, Visscher C, Meeusen R, Mulder T. Psychomotor speed: possibly a new marker for overtraining syndrome. *Sports Med*. 2006;36:817-28.
18. Buchheit M, Simpson BM, Garvican-Lewis LA, Hammond K, Kley M, Schmidt WF, Aughey RJ, Soria R, Sargent C, Roach GD, Claros JC, Wachsmuth N, Gore CJ, Bourdon PC. Wellness, fatigue and physical performance acclimatisation to a 2-week soccer camp at 3600 m (ISA3600). *Br J Sports Med*. 2013;47 Suppl 1:i100-6.
19. Saw AE, Main LC, Gastin PB. Monitoring the athlete training response: subjective self-reported measures trump commonly used objective measures: a systematic review. *Br J Sports Med*. 2015.
20. White DW, Raven PB. Autonomic neural control of heart rate during dynamic exercise: revisited. *J Physiol*. 2014;592:2491-500.

21. Hedelin R, Wiklund U, Bjerle P, Henriksson-Larsen K. Cardiac autonomic imbalance in an overtrained athlete. *Med Sci Sports Exerc*. 2000;32:1531-3.

Figure 1 – Changes in heart rate recovery (HRR) at all running intensities during the maximal incremental running test during the overload period. f-OR: functional overreaching.

Figure 2 – Typical example of HR and RPE responses before and after the overload training period in a participant developing functional overreaching (i.e. decreased performance and high perceived fatigue). Note that the HR and HRR responses at the beginning of the test (i.e. low intensity running) could suggest a good adaptation to training when considered in isolation. The combination with RPE values analysis indicates the development of the functional overreaching state.

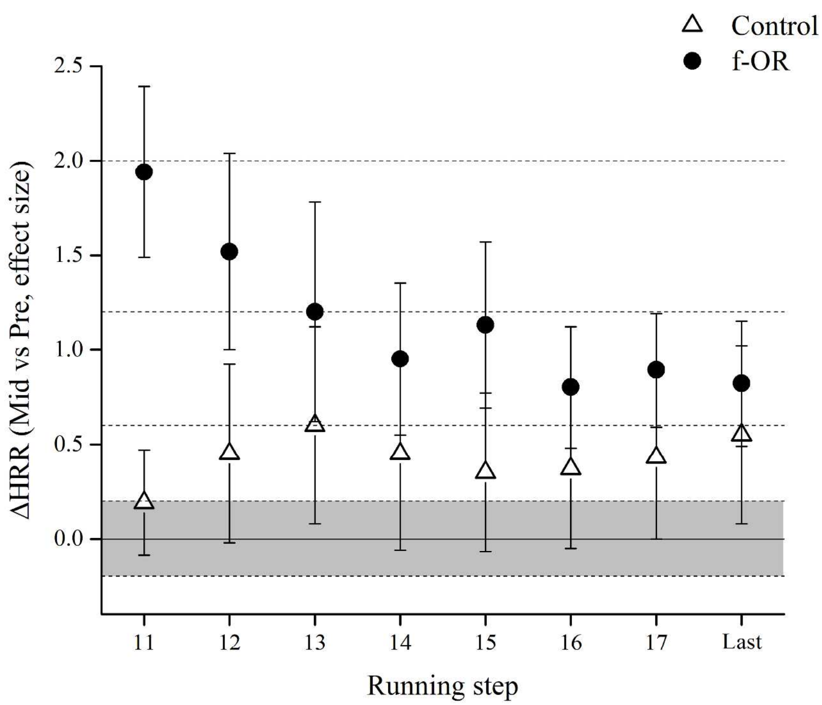

Figure 1 – Changes in heart rate recovery (HRR) at all running intensities during the maximal incremental running test during the overload period. f-OR: functional overreaching.
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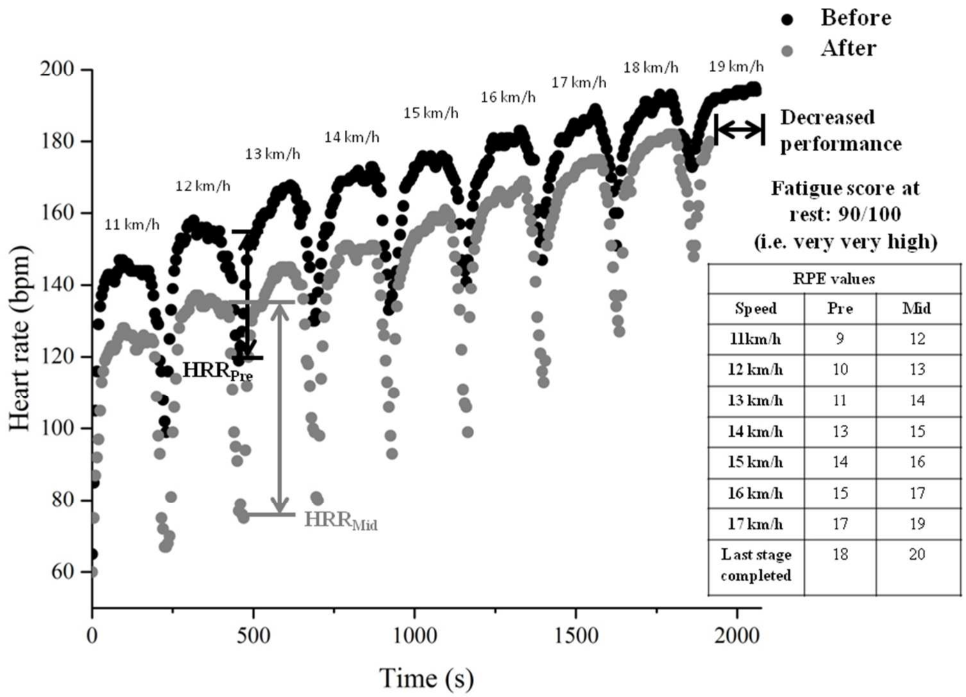

Speed	Pre	Mid
11km/h	9	12
12 km/h	10	13
13 km/h	11	14
14 km/h	13	15
15 km/h	14	16
16 km/h	15	17
17 km/h	17	19
Last stage completed	18	20

Figure 2 – Typical example of HR and RPE responses before and after the overload training period in a participant developing functional overreaching (i.e. decreased performance and high perceived fatigue). Note that the HR and HRR responses at the beginning of the test (i.e. low intensity running) could suggest a good adaptation to training when considered in isolation. The combination with RPE values analysis indicates the development of the functional overreaching state.
254x190mm (96 x 96 DPI)