Original research

Overload blunts baroreflex only in overreached athletes

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ABSTRACT

Objectives: Heart rate variability (HRV) is commonly used to diagnose overreaching and monitor athletes’
responses to training. Baroreflex sensitivity (BRS) is modified by changes in training load and might be
another means to detect overreaching. The goal of this study was to assess BRS and HRV changes in two
groups of athletes responding either negatively (FOR) or positively (AF) to similar training overload.

Design: Fifteen athletes performed 2-week baseline (BSL) training followed by 3-week overload (+45%;
OVL) and 2-week recovery (−20%; RCV).

Methods: HRV, training load and subjective fatigue were measured daily via questionnaires. BRS, salivary
cortisol and testosterone, and submaximal exercise and maximal 3-km run performances were measured
at the end of each period.

Results: Based on their performance change during OVL, 8 athletes were diagnosed as FOR and 7 as AF.
Subjective fatigue was increased in FOR athletes during OVL. BRS increased in AF but not in FOR athletes
during RCV. At the end of RCV, cortisol and testosterone were higher than BSL in both groups.

Conclusions: Three weeks of similar training overload can induce either performance enhancement or
overreaching. The changes in submaximal exercise and maximal performances and in subjective fatigue
were the fastest-responding parameters that distinguished the two groups of athletes during OVL. Training
overload blunted the increase in BRS in FOR only. Most of the differences in BRS were observed
during the recovery period. BRS appears to be a more sensitive parameter than HRV for early monitoring
of responses to training.

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1. Introduction

Optimization of training content and load is important for a wide range of people, from the beginner to the elite athlete. An adequate training process includes short-term performance decrements following training sessions alternated with recovery periods, which leads to performance improvement; this phenomenon is known as functional overreaching (FOR). Non-functional overreaching (NFOR) can occur when athletes do not sufficiently respect the balance between training and recovery periods.1 NFOR has been associated with an impaired cardiac response during exercise in endurance athletes, which is caused by a reduced adrenergic response to intense exercise as indicated by reduced catecholamine concentrations.2

Heart rate variability (HRV) is a commonly used method for diagnosing overreaching.3 Specifically, HRV analysis allows one to evaluate the modulation of the sympathetic and parasympathetic branches of the autonomic nervous system. Despite some issues, mostly regarding respiratory sinus arrhythmia,4 the low-frequency (LF) band mainly reflects the modulation of sympathetic influence on the heart.5 However, the LF band is also driven by parasympathetic tone and is believed to carry vagal resonances to either changes in the vasomotor tone (often sympathetic) or to the central modulation of the sympathetic tone.3 The spectral power in the LF band is related to fluctuations of the arterial blood pressure9 and to baroreflex activity.7 The HF band reflects the modulation of the parasympathetic influence on the heart and is mainly influenced by respiratory sinus arrhythmia.8 Endurance training increases parasympathetic tone.8 However, the best performance has been shown to be associated with hypotonia of both the sympathetic and the parasympathetic nervous systems.10,11 Hypotonia of one or the other is probably an early sign that the athlete has difficulty adapting to the training
load and may lead to overreaching. Finally, HRV-based methods have proven valid and reliable in the evaluation of stress and recovery.

There is much less in the literature concerning BRS in relation to sport performance, yet the baroreflex is a vital mechanism, affected by exercise and endurance training. BRS has been shown to decrease following a 1-week training overload period and to recover after three to four days in athletes. In elite athletes, it has been shown to decrease during the most overloaded period of the season (preparation for a world championship), while it was unchanged during the rest of the year.

Using a mathematical model, Manzi et al. predicted that BRS would increase up to an optimal training load and then would decrease with training overload. Finally, Le Meur et al. showed an impaired cardiac response during exercise associated with reduced catecholamine concentrations. BRS appears to be modified by training load; thus, it is a potential candidate that could contribute to the identification of the overloaded states in athletes.

To our knowledge, the changes in BRS during an overload period remain scarcely described in the literature concerning recreational athletes, but such changes may have a major impact on the athletes’ performance and health. In particular, while an improvement of the BRS would clearly correspond to a better cardiovascular health, a decrease would mark a deterioration of the health status. It is also fundamentally important to identify the quickest-responding parameter that allows the detection of overreaching, to enable the athletes or the coaches to control its onset.

The aim of the present study was to assess the changes in HRV and BRS in recreational athletes during three successive periods: baseline, overload and recovery. We tested the following hypotheses: (1) Athletes would respond in different ways (e.g., decreased vs. improved performance, i.e., acute fatigue vs. FOR) to the same overload. (2) Those specific responses in both HRV and BRS would yield an immediate diagnosis of FOR. (3) BRS would be more sensitive than HRV for the diagnosis of FOR.

2. Methods

This study consisted of three consecutive phases: a baseline period of two weeks (BSL), a training overload period of three weeks (OVL) and a recovery period of two weeks (RCV). During BSL, the participants continued to train as they did in the preceding three months, and their training loads were quantified. During OVL, the participants increased their training load by approximately 45% (the minimum acceptable threshold was set at 40%), and during RCV, training load was reduced slightly below the BSL level (approximately –20%).

Fifteen participants participated in this study (8 men, 7 women). The inclusion criteria were as follows: training at least 4 h/week in running or cycling (the addition of other physical activities such as cross-country skiing, team sports or rock climbing was an advantage), no injury or medication and no pregnancy or lactation in the three months preceding inclusion in the study. To ensure easy follow-up, we selected only participants who lived locally at the time of the study. All participants provided written informed consent prior to participation. The local ethical committee approved the study (agreement 2016-00308; Commission Cantonale d’Éthique de la Recherche sur l’être humain, CCER-VD; Lausanne, Switzerland). All experimental procedures conformed to the standards set by the Declaration of Helsinki.

The training load was assessed using Banister’s method. The heart rate (HR) was recorded with 1-Hz sampling frequency using an HR monitor (watch V800 + sensor H7 + chest belt, Polar, Kempele, Finland). The training load was computed as follows:

\[ W = \sum_{t_0}^{t_{final}} \frac{HR(t) - HR(\text{rest})}{HR(\text{max}) - HR(\text{rest})} \cdot 0.64 \cdot e^{1.92 \cdot \frac{HR(t)-HR(\text{rest})}{HR(\text{max})-HR(\text{rest})}} \]

\[ W = \sum_{t_0}^{t_{final}} \frac{HR(t) - HR(\text{rest})}{HR(\text{max}) - HR(\text{rest})} \cdot 0.86 \cdot e^{1.67 \cdot \frac{HR(t)-HR(\text{rest})}{HR(\text{max})-HR(\text{rest})}} \]

where Eq. (1) is used for male and Eq. (2) for female participants; \( HR(\text{rest}) \) corresponds to the mean HR in the supine position of the training-day orthostatic test (further details below); \( HR(\text{max}) \) is defined as 220 – age (in years); and the training load \( W \) is expressed in TRIMPs. The training sessions for all participants throughout the three phases were quantified as follows. During BSL, the experimenters quantified the training sessions performed by the participants. During OVL, the experimenters instructed the participants in modified and additional training sessions such that the training load was increased by at least 40% compared with BSL. The increase in training load was attained through increases in the duration and intensity of the training sessions. Finally, during RCV, the participants returned to their usual training habits, minus some sessions as instructed by the experimenters, in order to obtain a training load slightly below BSL (–20%). Training sessions were entirely individualized, using both interval-training and steady-state exercises. Participants were exposed to training contents adapted to their fitness and sport specialization, essentially based on running. During BSL, training was held 3–5 times/week; during OVL, training was held essentially daily; and in RCV training was held 2–4 times a week. A standardized period of recovery was provided prior to performance testing in each phase of the study, according to each participant’s training and competition programme.

The submaximal exercise and maximal performance tests occurred outdoors, on a 400-m track adjoining the laboratory, under the supervision of the experimenters, on the last days of BSL, OVL and RCV. The submaximal test consisted of 3 periods of 5 min during which running speed was self-adjusted so that the HR would equal 80% of maximal HR. Two-minute recovery periods (walking) separated the 5-min running periods. After the submaximal test, a 6-min period of recovery (walking) was observed before the maximal test. The latter consisted of a 3-km running time trial, with the verbal encouragement of the experimenters. Throughout both types of test, the participants wore the HR monitor previously described.

During the submaximal test, the average running speed (km/h) over the three 5-min sessions was recorded as an index of submaximal exercise that potentially reflected a state of overreaching. In all trials, all participants ran at comparable imposed HR. Time to completion of the 3-km run was recorded as an index of maximal performance.

The participants performed either a “3–3” (3 min in the supine position followed by 3 min in standing position) or a “6–6” (6 min supine followed by 6 min standing) orthostatic test immediately after waking up in the morning. The 3–3 test was performed daily, whereas the 6–6 test was performed every third day, using an interbeat interval (RR interval) measuring device (identical to the HR monitor). The rationale was that the 3–3 procedure diminished the daily constraint and improved comfort for the participants, while the 6–6 procedure, which was more time consuming, would ensure a better reliability. In Section 3, data from both procedures were compiled, as the 3–3 procedure showed satisfying reliability. The participants set up the chest belt and the sensor, set the watch to RR mode and started recording the RR intervals for three (or six) minutes in the supine position, immediately followed by three (or
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