Evaluating Training Adaptation With Heart-Rate Measures: A Methodological Comparison

Daniel J. Plews, Paul B. Laursen, Andrew E. Kilding, and Martin Buchheit

The aim of this study was to compare 2 different methodological assessments when analyzing the relationship between performance and heart-rate (HR) -derived indices (resting HR [RHR] and HR variability [HRV]) to evaluate positive adaptation to training. The relative change in estimated maximum aerobic speed (MAS) and 10-km-running performance was correlated to the relative change in RHR and the natural logarithm of the square root of the mean sum of the squared differences between R-R intervals on an isolated day (RHRday; Ln rMSSDday) or when averaged over 1 wk (RHRweek; Ln rMSSDweek) in 10 runners who responded to a 9-wk training intervention. Moderate and small correlations existed between changes in MAS and 10-km-running performance and RHRday (r = .35, 90%CI [–.35, .76] and r = –.21 [–.68, .39]), compared with large and very large correlations for RHRweek (r = –.62 [–.87, –.11] and r = .73 [.30, .91]). While a trivial correlation was observed for MAS vs Ln rMSSDday (r = –.06 [–.59, .51]), a very large correlation existed with Ln rMSSDweek (r = .72 [.28, .91]). Similarly, changes in 10-km-running performance revealed a small correlation with Ln rMSSDday (r = –.17 [–.66, .42]), vs a very large correlation for Ln rMSSDweek (r = –.76 [–.92, –.36]). In conclusion, the averaging of RHR and HRV values over a 1-wk period appears to be a superior method for evaluating positive adaption to training compared with assessing its value on a single isolated day.

Keywords: monitoring, cardiac parasympathetic function, heart-rate variability

Athletes, coaches, and sport science practitioners seek useful methods to monitor individual adaptation or maladaptation to training. It has been shown that heart-rate (HR) -derived indices such as morning resting HR (RHR) and HR variability (HRV) decrease and increase, respectively, after endurance-training regimens and may therefore represent an easy-to-use, noninvasive means by which to assess individual adaptation to endurance training.1

During the monitoring of an elite triathlete who developed signs of maladaptation to training, we recently identified a number of methodological issues associated with determining adaptation using isolated (ie, single-day) RHR and HRV readings.2 Factors such as noise, temperature, light,3 and prior exercise4 can affect HRV on any given day. In the former article,2 we showed that RHR and HRV data, displayed as rolling or weekly averages, appeared to provide a more consistent representation of the changes in fatigue and maladaptation. As suggested previously, the use of isolated daily values to measure changes in HRV has likely led to the equivocal findings reported throughout the HRV training literature.2

Given the potential of this alternative methodological approach, we revisited the RHR and HRV data taken from recreationally trained runners who responded positively to a 9-week training intervention.5 To assess the best practical methodological approach to analyze positive adaptation to a training intervention, we compared the relationship between isolated versus weekly-averaged RHR and HRV values and running performance.

Methods

Participants

Out of the 14 runners described in the original study,5 10 of the positive responders (mass 75.6 ± 7.4, estimated maximum aerobic speed [MAS] 17.3 ± 1.7 km/h, 10-km 48:34 ± 7:45 min:s) were selected for further assessment to allow fair comparison between 2 different methodological approaches. Only 10 responders were included for further analysis (compared with n = 11 in the original paper5), due to limited availability of data in the final week of the training intervention for 1 subject, which would make comparison between single-day and weekly-averaged values invalid.
Experimental Protocol

Details of the 9-week training intervention, estimated MAS, and 10-km-running assessment, as well as RHR and HRV recordings, have been described previously. Only morning RHR and HRV measures were analyzed in the current study, as these have superior practicality for regular monitoring. HRV values were restricted to the natural logarithm of the square root of the mean sum of the squared differences between R-R intervals (Ln rMSSD), as Ln rMSSD has much greater reliability than other spectral indices.

Statistical Analysis

Weekly data are expressed as mean ± SD. Measures including the coefficient of variation (CV), smallest worthwhile change (0.2 multiplied by the between-subjects SD), magnitude of correlation (r), 90% confidence intervals (90%CI), and Cohen effect sizes (ES) were determined. Data were compared between single-day (Tuesday due to consistent data points) and weekly-averaged (Saturday to Friday) RHR (RHRday, RHRweek) and Ln rMSSD (Ln rMSSDday, Ln rMSSDweek) values. Pearson product–moment correlation analysis was used to compare the association between the relative (%) change (from week 1 to week 9) in HR-derived indices (day and week) and performance.

Results

The mean CVs for RHRday, RHRweek, Ln rMSSDday, and Ln rMSSDweek recorded over 9 weeks were 13.0%, 12.2%, 18.7%, and 16.5%, respectively.

Group weekly differences in both RHR and Ln rMSSD (isolated day and weekly) relative to the smallest worthwhile change are shown in Figure 1. From weeks 1 to 9, RHRday changed by –10.3% ± 6.5% (ES = –0.66), compared with –8.9% ± 3.2% (ES = –0.64) for RHRweek. Conversely, Ln rMSSDday changed by 4.3% ± 10.3% (ES = 0.20) compared with 9.6% ± 4.8% (ES = 0.46) for Ln rMSSDweek.

There were moderate and small correlations between percentage change in both MAS and 10-km-running performance and RHRday (r = .35 90%CL [−.35, .76] and

Figure 1 — Changes in single-day and weekly-average resting heart rate (RHRday and RHRweek) and natural logarithm of the square root of the mean sum of the squared differences between R-R intervals (Ln rMSSDday and Ln rMSSDweek). The shaded areas represent the smallest worthwhile change (ie, within group SD x 0.2 during the first week; see Buchheit et al). Values are group mean ± SD.
Correlations were large and very large against RHR$_{\text{week}}$ ($r = -0.62 [-0.87; -0.11]$ and $r = 0.73 [0.30, 0.91]$).

The correlation between relative changes in performance (MAS and 10 km) and Ln rMSSD (isolated day and weekly data) are shown in Figure 2.

**Discussion**

As shown previously in an elite triathlete displaying signs of maladaptation, the use of isolated daily HRV data points may be less accurate than using weekly averages to assess adaptation to training. In the current study, we have demonstrated that large day-to-day variation in RHR and HRV (CV = 18.7% and 16.5%) can sometimes lead to a misinterpretation of the “true” change due to training. For example, Figure 1 shows how Ln rMSSD$_{\text{day}}$ returns to within the smallest worthwhile change on week 9 when athletes are at their fittest; this is not the case when Ln rMSSD values are averaged over a week. Furthermore, large and very large correlations existed against relative changes in both MAS and 10-km-running performance only when RHR and Ln rMSSD values were averaged over 1 week (Ln rMSSD represented in Figure 2). As such, we suggest that practitioners use this new averaging method of RHR and HRV analysis to acquire a more meaningful assessment of positive adaptation or maladaptation to training regimens.

Measuring daily RHR is a more common and practical method of assessing cardiorespiratory fitness and in this instance appears to have provided a closer representation of adaptation than Ln rMSSD when considered on a single day (change from week 1–9: ES = -0.66 RHR$_{\text{day}}$ and -0.64 RHR$_{\text{week}}$ vs ES = 0.20 Ln rMSSD$_{\text{day}}$ and 0.46 Ln rMSSD$_{\text{week}}$). This could be due to lower day-to-day variation in RHR observed in the current study (CV = 13.0% RHR$_{\text{day}}$ and 12.2% RHR$_{\text{week}}$, CV = 18.7% Ln rMSSD$_{\text{day}}$ and 16.5% Ln rMSSD$_{\text{week}}$) and other studies. While we acknowledge that physiological training adaptations are the consequence of many factors, longitudinal HRV data are perhaps a slightly more sensitive measure for tracking changes in fatigue and fitness when averaged over a 1-week period. However, RHR may provide a better indication of training state if only single-day values are available.

*Figure 2* — Relationship between relative changes in maximal aerobic speed (MAS) and 10-km-running performance and relative changes in single-day and weekly-average natural logarithm of the square root of the mean sum of the squared differences between R-R intervals (Ln rMSSD$_{\text{day}}$ and Ln rMSSD$_{\text{week}}$) with 90% confidence intervals.
References


