Fine-tuning training strategy based on heart rate variability: A case study of a middle-distance runner

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Headline

Heart rate variability (HRV) is considered a global marker of homeostasis and is used as an indicator of recovery state in athletes. Smartphone applications (e.g., Elite HRV, HRV4) make it possible for athletes to easily measure daily HRV. A recent study has shown that monitoring the magnitude of daily fluctuation in logarithm of the root mean square differences between adjacent normal R–R intervals (Ln RMSSD) is a sensitive response marker (1).

Aim

In most previous studies conducting training prescription guided by HRV, HRV is used to judge whether training should be hard or easy (2, 3). However, the training of athletes is not such two-way things. Rather, the athletes should adjust their daily training menu (e.g., reduce the number of intervals, increase the duration of low-intensity training). In the present study, we report a fine-tuning training strategy using HRV of a graduate student who was a middle-distance runner.

Methods

Athletes. A male graduate student middle distance runner (age: 22 years, height: 175 cm, weight: 60 kg) started HRV recording from April 2018. He ranked sixth in a national tournament in a high school in Japan (an interscholastic athletic meet). However, he was unable to get a good rank in tournaments during his four years of undergraduate studies. Before starting HRV recording, his personal record was 1:52.85 and 3:51.38 for 800 m and 1500 m, respectively.

Design. The present study is a single case report. We reported HRV and training load for 23 weeks from April 2018 to September 2018. In September, the most important competition was taking place (Japan student athletics championship tournament: JSACT). The time standards were set for the JSACT. The runner was unable to participate in the JSACT during the four years of his undergraduate studies.

The runner recorded daily HRV after waking up. In addition, the runner recorded the daily training load (volume and intensity) in an excel file. These data were routinely collected as part of the conditioning program without the ethics committee approval. Nonetheless, the present study conforms to the recommendations of the Declaration of Helsinki.

HRV. The runner recorded the resting HRV for 120 s in the supine position after waking up. The runner was allowed to breathe spontaneously. The HRV was recorded with a bluetooth chest-strap (H10 sensor, Polar Electro, Kempele, Finland) paired with a freely available smartphone application (Elite HRV, Asheville, North Carolina, USA). The elite HRV had been validated in the previous study (4). We used Ln RMSSD because it is the most practically applicable HRV index in the field setting. Because the recent study suggested that the coefficient of variation of Ln RMSSD (CV Ln RMSSD) is a more sensitive training response marker, the CV Ln RMSSD was evaluated as the primary outcome (1). In addition, the 7-day rolling average of Ln RMSSD (7-day rolling Ln RMSSD) was calculated (5).

The runner tweaks his daily training menu based on the morning Ln RMSSD of the day. When the Ln RMSSD was lower than usual (Ln RMSSD less than 4.5 ms, based on the average for the first two weeks), the runner avoided high-intensity training or reduced the number of intervals. More specifically, if the runner judged that Ln RMSSD dropped significantly from 4.5 ms, high-intensity training was avoided. If the runner judged that Ln RMSSD dropped only a little, the number of intervals was reduced. The important thing is that the runner received feedback on Ln RMSSD daily from the smartphone application and changed the daily training set so that the fluctuation in Ln RMSSD was small. Before the start of this approach, the runner received a lecture from the Certified Strength and Conditioning Specialist regarding the effects of training and activity of daily life on HRV.

Table 1. Weekly value of HRV and training

		Mean±SD
HRV	Mean Ln RMSSD (ms)	4.63±0.11
	CV Ln RMSSD (%)	4.53±1.53
Training	Zone 1 (km)	55.6±21.7
	Zone 2 (km)	3.1±4.3
	Zone 3 (km)	3.2±2.5
	Zone 4 (km)	3.5±2.0
	Zone 5 (km)	1.0±0.7
	Total (km)	66.2±26.0

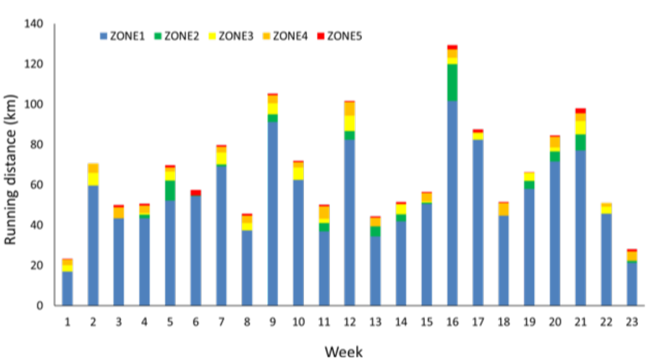

Fig. 1. Weekly changes in training load.

Hooper's score. Psychological state was assessed using the Hooper Questionnaire (6). The items of the questionnaire were sleep, stress, fatigue, and muscle soreness. The four subjective ratings were recorded on a scale ranging from 1 to 7 (with 1 representing "very very good" and 7 representing "very very bad"). Hooper's score is determined by summing the four scores. The runner completed the questionnaire every morning after the HRV recording.

Training load. The runner recorded the daily training load (volume and intensity) in an excel file. Training intensity was based on the distribution into three aerobic zones: Zone 1: easy and moderate continuous running; Zone 2: threshold intervals; Zone 3: harder aerobic intervals and anaerobic specific zones; Zone4: fast repetition over shorter distances. Hills or track training at 800-m and 1500-m pace; Zone5: Sprint and strides based on a previous study (7).

Statistical analysis. Weekly analysis was conducted for HRV, Hooper's score, and training load. For 7-day rolling Ln RMSSD, the smallest worthwhile change (SWC) was determined as mean±0.5 standard deviation (5). The reference value was the first 2 weeks Ln RMSSD value.

Results

The HRV and training load are presented in Table 1. The weekly training load is presented in Figure 1. The weekly mean Ln RMSSD was 4.63±0.11 ms, whereas weekly CV Ln RMSSD was 4.53±1.53%. Figure 2 shows daily changes in Ln RMSSD and 7-day rolling Ln RMSSD. The gray area indicates the SWC of Ln RMSSD. The 7-day rolling Ln RMSSD was below SWC for 6 days. In the latter half, the 7-day rolling Ln RMSSD exceeded SWC because Ln RMSSD tended to be higher. Figure 3 shows weekly changes in Hooper's score. The weekly Hooper's score repeatedly increased and decreased.

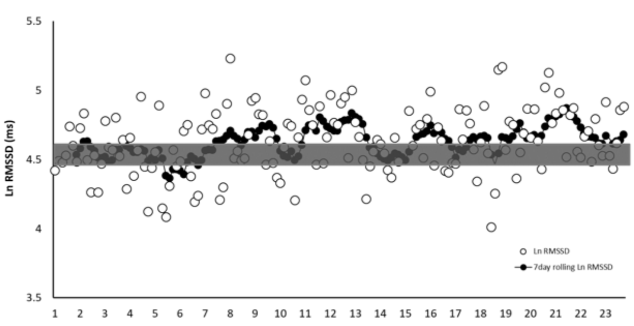

Fig. 2. Daily changes in Ln RMSSD, 7-day rolling Ln RMSSD. The gray area indicates the SWC of Ln RMSSD.

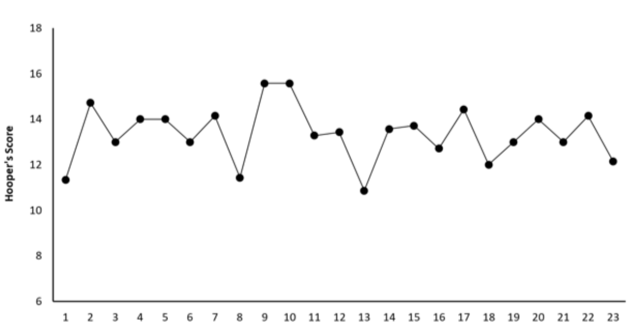

Fig. 3. Weekly changes in Hooper's score.

The data on training load, HRV, and Hooper's score are in the supplemental file. The runner updated his self-record of 800 m twice (1:51.78 and 1:50.98) and of 1500 m once (3:49.10). In addition, he ranked seventh in the Japan University Student Individual Championship in June. He could participate for the first time in JSACT and become a semifinalist at 800 m. In this 23-week period, there was no interruption in training due to sick or injury.

Discussion

The runner was able to have a successful season for the first time in 4 years. The main finding in the present study was that weekly CV Ln RMSSD was small throughout the 23-week period. Moreover, the latter half of the period, the 7-day rolling Ln RMSSD, exceeded the SWC because the value tended to be higher. Previous studies have shown that CV Ln RMSSD is an effective marker for the evaluation of training adaptation in team sport athlete or endurance athlete (1,8). For example, Flatt and Howells (1) investigated weekly HRV responses over a 3-week period (week 1: baseline, weeks 2–3: intensified training) in Olympic rugby sevens athletes and reported that smaller weekly CV Ln RMSSD during the first week of intensified training showed more favorable changes in maximal aerobic speed. For a collegiate male cross-country athlete, Flatt and Esco (8) measured HRV and endurance race performance throughout a competitive season. In this report, they observed a strong relationship between 8-km race time and weekly CV Ln RMSSD (r=0.92). These previous data suggested that small fluctuations in Ln RMSSD is an important factor for producing training adaptation.

It seems that the weekly CV Ln RMSSD in the runner (4.53±1.53%) is relatively smaller than that shown in previous reports (8,9). For example, the CV over 9 weeks has a minimum value of 5.5%, maximal value of 21.4%, and mean value of 11.3% in the collegiate male cross-country athlete as mentioned above (8). It had also shown that the CV Ln RMSSD was 5%–7% in elite endurance athletes and ∼10% in recreational runners (9). Thus, we speculated that the reasons for better performance during the 23-week period may be attributable to a small fluctuation in Ln RMSSD.

The 7-day rolling Ln RMSSD exceeded SWC in the latter half of the period, suggesting increase in parasympathetic modulation. Da Silva et al. (10) evaluated HRV and aerobic performance before and after 7 weeks of training in 6 male endurance runners at the national level and reported that a positive correlation was found between mean speed at 5-km running and % change in RMSSD. This result suggested that increasing the parasympathetic modulation has a positive effect on endurance performance. Indeed, the previous study suggested that both the increase in mean value and small variation of RMSSD were related to positive adaptation in athletes (11). Therefore, we need to pay attention not only to the fluctuation but also the mean value of HRV (i.e., 7-day rolling Ln RMSSD).

Several previous studies have shown that RMSSD is increased in response to overload training leading to attenuated performance (overreaching) (12-14). In these previous studies, the subjective markers (Daily Analysis of Life Demands for Athletes, Visual Analog Scale) had deteriorated along with the increase in HRV (12-14). In the present study, the Hooper's score repeatedly increased and decreased and did not continuously deteriorate (Figure 3), suggesting that the runner had not overreached. Bellenger et al. (12) argued that subjective measures may be used to facilitate appropriate interpretation of HRV because HRV increased in response to functional overreaching and improvement in performance.

Therefore, RMSSD should be interpreted together with subjective markers.

Practical Applications

- Middle distance runners should use the feedback from smartphone applications so that the fluctuation of Ln RMSSD is small.
- Both objective (HRV) and subjective (Hooper's score) criteria are important for assessment of middle-distance runners conditioning.

Limitations

- The present case study does not necessarily imply a cause–effect relationship; thus, this information should be interpreted cautiously.

Conflicts of Interest

FT currently belongs to KDDI Research, Inc. All authors declare that there is no conflict of interests regarding the publication of the manuscript.

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