Monitoring Ultra-Short Heart Rate Variability and Heart Rate-Running Speed Index in an Elite Soccer Player: A Case Study

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Monitoring | Heart-rate variability | Fatigue | Soccer | Case study

Headline

Sport scientists aim for balance between fitness and fatigue on the training response continuum to assure their athletes achieve optimal physiological adaptations (1). Implementing non-invasive, non-exhaustive, inexpensive, and valid methods, on a regular and individual basis is the key for optimal monitoring of professional athletes (2). During recent years, there seems to be interests to shift from maximal testing to submaximal and resting alternatives when monitoring athletes in the field-based settings (3-8).

Heart-rate (HR) derived measures including HR variability (HRV) and exercise HR (HRex) are among the top practical tools for monitoring athletes' training response (2). While traditional HRV analysis needs 5-min R-R data recording in resting condition (2), recent studies suggest using ultra-short term (1-min) as a more time-efficient alternative (4, 9). Although multiple studies have demonstrated the sensitivity of ultra-short term HRV for monitoring athletes' training status (4-6), the within-individual relationship between 5-min and 1-min HRV has yet to be reported over a longitudinal period.

Different submaximal tests have been suggested to collect valid HRex values for monitoring purposes in athletes (2). More specifically, a practical submaximal warm-up test (SWT) has been recently proposed to simplify the regular monitoring of professional soccer players (7,8). This test, similar to other submaximal tests, needs to be controlled in terms of running velocity using audio signals which may limit its regular usage in high-level soccer. Heart rate-running speed (HR-RS) Index has been proposed for monitoring aerobic adaptation without the need for controlling running velocity if the training nature is aerobic-oriented and almost constant (10). HR-RS is an index representing the absolute difference between the theoretical and actual running speed (10). The HR-RS equation, described previously (10), includes the average speed, peak speed, and HRex from submaximal running as well as standing HR. However, the nature of soccer training is intermittent including various anaerobic activities (e.g., accelerations, decelerations, change of directions, jumping, etc.) except the early part of training sessions (i.e., general warm-up, jogging) (11). Therefore, whether HR-RS index derived from a short jog (4 to 5 min) improves during a preparation phase in a professional soccer player requires investigation. If the use of HR-RS Index derived from the general warm-up jogging shows promise, the need for controlling running velocity for SWT can be eliminated, making the monitoring process even more practical.

Aim. The aims of the present case study were 1) to quantify training adaptation using resting HRV and HR-RS Index and 2) to examine the within-individual relationship between 1-min and 5-min HRV and their possible associations with HR-RS Index in an elite soccer player during his preparation phase

Methods

Athletes. A male midfield soccer player (age = 22 y, height = 190 cm, mass = 83.2 kg, $\dot{V}O_{2max}$ = 58.2 ml·kg^{-1}·min^{-1} and body fat = 7.1%) from a professional team competing in the Iran Professional League and Asian Football Confederation Champions League agreed to participate in the present study. The player provided informed consent before commencing data collection and the study was approved by the local institutional research ethics committee.

Design. The study was conducted during the pre-season preparation phase of the 2018-2019 season. The session rating of perceived exertion (sRPE) was collected using the CR10 scale (12) for all training sessions (n = 46 sessions including 19 Gym and 27 field sessions) during the selected phase (n = 33 days). In early, mid, and late 5-day blocks of the training period, wellness, HRV and HR-RS Index were recorded. Hooper Index, as an overall wellness measure, was computed by summing four subsets (i.e. perceived sleep quality and quantities of stress, muscle fatigue, and muscle soreness) (13) provided by the player each morning, on a daily basis. The player used a GPS sports watch (Polar V800) synchronized with a Bluetooth heart rate sensor (H10, Polar Electro, Kempele, Finland) for collecting resting R-R data during mornings as well as HRex and running velocity during the first 4-min jogging of field sessions for analyzing HR-RS Index. The Polar V800 has been validated against electrocardiograph for R-R interval recording (14). R-R recordings lasted for 5-min under spontaneous breathing conditions in the seated position after waking. R-R data were then exported and further analyzed using Kubios HRV 2.2 software for calculating log-transformed root mean square of successive R-R intervals (Ln RMSSD). For analyzing 1-min Ln RMSSD, the second min period was used, preceded by the first min for stabilization assurance (15). HR-RS Index was computed using the average heart rate and running speeds (average and speed peak) collected during the first 4 min of jogging exercise implemented in the early part of selected field-based training sessions using the equation provided by Vesterinen et al. (10). The average HR collected for HR-RS Index was adjusted based on the local temperature. The mean temperature during the selected 15 days (i.e., 3 blocks of 5-day phases) was 32.1 ºC (ranging from 29 to 35.3 °C) with coefficient of variation (CV) of 5.9%.

Analyses. The relationship between 1-min and 5-min Ln RMSSD and their associations with HR-RS Index were analyzed using Pearson correlation coefficients. The magnitudes of correlations (r, 90% CLs) were determined based on the scale provided by Hopkins et al. (16). The 5-day averages of sRPE, HRV, and HR-RS Index were computed for analysis. The standardized difference (effect size, ES) was used to determine differences between 5-day averages of monitoring variables in blocks based on Cohen's d principle (17). The

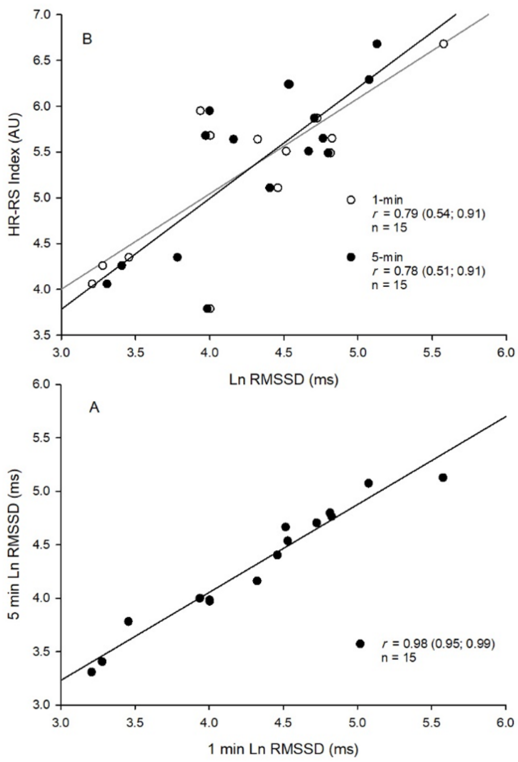

Fig. 1. A) Relationship between 1 min and 5 min log-transformed root mean square of successive R-R intervals (Ln RMSSD). B) Relationship between Ln RMSSD and heart rate-running speed index (HR-RS Index).

Table 1. Mean (90% CI) values for perceived fatigue at rest before (Pre), after the overload training period (Mid) and at the end of the taper (Post) in both groups.

Variable	Effect size, qualitative inferences		
	2 vs. 1 block	3 vs. 2 block	3 vs. 1 block
sRPE (AU)	-0.05, trivial	0.72, moderate	0.96, moderate
1-min Ln RMSSD (ms)	2.88, very large	0.79, moderate	3.79, very large
5-min Ln RMSSD (ms)	2.72, very large	0.68, moderate	3.68, very large
HR-RS Index (AU)	1.53, large	0.91, moderate	1.99, large
Hooper Index (AU)	-0.6, small	1.6, large	0.6, small

Each block includes 5 consecutive days. sRPE: session rating of perceived exertion; Ln RMSSD (ms): log-transformed root mean square of successive R-R intervals. HR-RS Index: heart rate-running speed index; AU: arbitrary unit.

threshold values used for interpreting ES statistics were as follows; trivial (0.0–to–<0.2), small (0.2–to–<0.6), moderate (0.6–to–<1.2), large (1.2–to–<2), and very large (>2.0) (18).

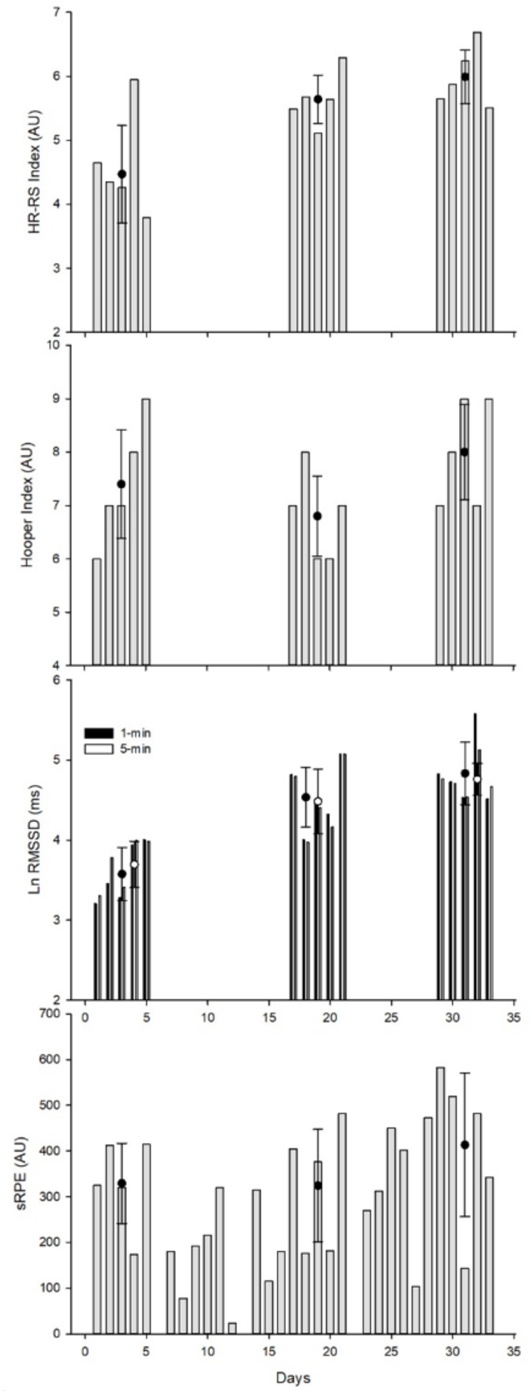

Fig. 2. Training load and monitoring variables during selected phase. Dot symbols represent 5-day averages.

Results

The mean sRPE during all training days was 299 (AU) with the CV of 48%. The mean running velocity derived from the first 4-min of training sessions during the selected 15 days for computing HR-RS Index was 10.8 km·h^{-1} with a CV of 12%. The results showed a likely trivial difference between ultra-short term (1-min) and 5-min HRV (% difference, 1.8, 90% confidence interval [0.1 to 3.6]; effect size, 0.11, [0.01 to 0.21]). A nearly perfect within-individual relationship was observed between ultra-short (1-min) and 5-min HRV in the subject (Fig. 1/A). Very large within-individual associations were observed between 1-min and 5-min Ln RMSSD with HR-RS Index (Fig. 1/B).

Training load and monitoring variables as well as their 5-day averages during the selected phases are shown in Fig 2.

Standardized differences of training load and monitoring variables during the selected phase are presented in Table 1.

Discussion

This is the first study that quantified training adaptation using HR-RS Index in a professional soccer player during his preparation phase. In the present study, the within-individual relationship between 1-min and 5-min Ln RMSSD and also their possible associations with HR-RS Index was also investigated for the first time. The results showed a nearly perfect association and likely trivial difference between 1-min and 5-min Ln RMSSD. This finding supports previous recommendations of using ultra-short term HRV recordings (3, 5, 9, 19) which in our case (for 15 training sessions) could save 45 min of the subjects' busy schedule for data collection. Moreover, both 1-min and 5-min Ln RMSSD showed very large associations with HR-RS Index (n = 15 training sessions). Progressive reductions in submaximal HRex and increases in HRV have been associated with increased plasma volume and improvements in aerobic fitness among soccer players in response to training in the heat (20). Taken with the observed large and very large improvements in HR-RS Index and Ln RMSSD (both 1-min and 5-min) after preparation, it seems that these measures are effective for monitoring professional athletes' fitness status during short term training phases.

Although using SWT needs to control the running velocity at a constant speed (i.e., 12 $km{\cdot}h^{-1}$) (7, 8), the results of the present case study showed that using HR-RS Index can eliminate this need, providing further practical applications in the real world scenario. The greater improvements of HR-RS Index and Ln RMSSD in block 2 compared to block 1 (large and very large changes) relative to changes from block 2 to block 3 (moderate changes) suggests faster physiological improvement during early phases of training among this athlete. The change in sRPE was trivial when block 2 was compared to block 1. The observed small improvement in wellness status in block 2 compared to block 1 again suggests that the player has coped psychologically well with the training stress. The moderate increase in sRPE observed in block 3 with only a small impairment of Hooper Index when comparing block 3 to block 1 suggests that player's wellness has not been drastically impaired during the final parts of preparation. Collectively, this case report demonstrates that more convenient resting and sub-maximal HR-derived measures show promise for reflecting training adaptations in elite athletes, warranting further research with larger sample sizes.

Practical Applications

- Resting Ln RMSSD and HR-RS derived from the early part of training sessions may be useful for tracking a professional soccer players' progressive improvement in fitness
- Performing 1-min rather than 5-min Ln RMSSD measures seems to provide similar values and relationships with HR-RS and demands less of the athletes' time, which may enhance daily compliance.
- The HR-RS seems to be a more convenient alternative to more strictly standardized submaximal HRex tests that demonstrated expected progressive improvements throughout preseason training in this athlete.

Limitations

- The results are limited by the analysis of only one subject. This study also lacks having laboratory-derived fitness measures and external training load during the experiment.

Acknowledgments. The authors thank the player for his enthusiastic participation. The authors declare no conflict of interest.

Dataset

Dataset available on SportPerfSci.com

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