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Assessing Shortened Field-Based Heart-Rate-Variability-Data Acquisition in Team-Sport Athletes

Lucas A. Pereira, Andrew A. Flatt, Rodrigo Ramirez-Campillo, Irineu Loturco, and Fabio Y. Nakamura

Purpose: To compare the LnRMSSD and the LnRMSSD:RR values obtained during a 5-min stabilization period with the subsequent 5-min criterion period and to determine the time course for LnRMSSD and LnRMSSD:RR stabilization at 1-min analysis in elite team-sport athletes. ***Participants:*** 35 elite futsal players (23.9 ± 4.5 y, 174.2 ± 4.0 cm, 74.0 ± 7.5 kg, 1576.2 ± 396.3 m in the Yo-Yo test level 1). ***Methods:*** The RR-interval recordings were obtained using a portable heart-rate monitor continuously for 10 min in the seated position. The 2 dependent variables analyzed were LnRMSSD and LnRMSSD:RR. To calculate the magnitude of the differences between time periods, effect-size (ES) analysis was conducted. To assess the levels of agreement, intraclass correlation coefficients (ICC) and Bland-Altman plots were used. ***Results:*** The LnRMSSD and LnRMSSD:RR values obtained during the stabilization period (0–5 min) presented very large to nearly perfect ICCs with the values obtained during the criterion period (5–10 min), with trivial ESs. In the ultra-short-term analysis (ie, 1-min segments) the data showed slightly less accurate results, but only trivial to small differences with very large to nearly perfect ICCs were found. ***Conclusion:*** LnRMSSD and LnRMSSD:RR can be recorded in 5 min without traditional stabilization periods under resting conditions in team-sport athletes. The ultra-short-term analysis (1 min) also revealed acceptable levels of agreement with the criterion.

Keywords: cardiac autonomic system, futsal, court sports, athletic monitoring

Heart-rate variability (HRV) is a practical and noninvasive tool for monitoring cardiac autonomic function in both healthy and clinical populations.[1] HRV has been used to assess training-load responses and physiological adaptations in athletes of various individual and team sports.[2–4] For example, improvements in vagally mediated HRV indices are often associated with aerobic-capacity changes after longitudinal training programs.[5,6] Other research supports HRV-guided training in favor of traditional approaches for improving endurance performance.[7–9] In this case, training loads are adjusted to maintain resting HRV at or above baseline values, as prolonged reduction or excess variation of HRV can lead to inferior performance improvement[9] or even overreaching.[10] Of the vagal-HRV indices, the natural log of the root-mean-square difference of successive normal RR intervals (LnRMSSD) appears to be the most appropriate index for field assessment. This is due to its reliability[11] and sensitivity to detect physiological adaptations and to its simplicity in calculation and interpretation.[2–4]

For meaningful assessment of training status, daily HRV recording is preferred over less frequent measures (eg, once per week) due to its capacity to monitor/quantify the training responses.[3,12] This has resulted in an increased interest in the development of more-convenient field HRV tools in addition to shorter and more convenient HRV-recording methodology.[13,14] Traditionally, it has been recommended that a period of 10 minutes be used to assess HRV in athletes,[15] where the first 5 minutes typically serve as a stabilization period, preceding the last 5 minutes, where resting HRV-data acquisition is completed (ie, criterion period). However, previous research has demonstrated excellent agreement between randomly selected 60-second LnRMSSD values and those obtained during the criterion period during electrocardiograph (ECG) recordings in college athletes[13] and nonathletic subjects.[16,17] Nevertheless, in these investigations ECG-data acquisition followed a traditional 5-minute stabilization period.[13,16,17] In contrast, recent work by Flatt and Esco[14] with college athletes showed that LnRMSSD values obtained during any 60-second interval within the stabilization period of supine ECG measures showed no difference compared with the criterion period. Collectively, these results indicate that a 60-second supine LnRMSSD recording preceded by a minimal (~60-second) stabilization period may be suitable for HRV assessment in athletes. It must be mentioned that, in the aforementioned studies,[13,14,16,17] HRV data were obtained only during supine ECG recordings in controlled laboratory settings, limiting the applicability of these results to field assessment due to the high economical cost and subjects' preparation needs associated with ECG measures. Therefore, investigation into shorter and more-convenient recording methodology that can be applied in field settings with convenient field HRV-assessment tools is required.

Seated HRV recordings have recently been suggested as the preferred measurement position in highly fit athletes,[4] mostly to counteract the vagal saturation of cardiac control, characterized by a ceiling of the R-R interval length versus vagal-related HRV indices in the region close to the attainment of maximum R-R-interval values.[18] This phenomenon may obscure the identification of training effects on HRV. In addition, the ratio of LnRMSSD to R-R interval (LnRMSSD:RR) has been an important parameter for interpreting training status in elite athletes that was not included in previous work. Reduced LnRMSSD:RR suggests vagal saturation, while an increased ratio denotes increased sympathetic activity.[3] This index has been shown to be useful in combination with LnRMSSD to monitor training effects in endurance athletes. For

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instance, in an interesting case study, a small decrease in LnRMSSD accompanied by a trivial change in LnRMSSD:RR was related to suboptimal competitive performance in triathlon, while a moderate decrease in both LnRMSSD and LnRMSSD:RR was related to optimal performance.[19] Finally, athletes will self-perform HRV measures in field settings, which are unlike the tightly controlled settings of the laboratory. Hence, an important next step is to evaluate the suitability of shorter, more-convenient recording methodology in highly fit subjects in the seated position with a validated field tool before practitioners adopt these modified recording protocols.

Thus, the aim of this study was to compare the LnRMSSD and LnRMSSD:RR values obtained during a 5-minute stabilization period with values obtained during the subsequent 5-minute criterion period in elite team-sport athletes from seated field measures with a valid field tool. A secondary objective was to determine the time course for LnRMSSD and LnRMSSD:RR stabilization to assess at which minute these variables showed no difference from the criterion period. We hypothesized that the values obtained during the stabilization period would not significantly differ from those obtained during the criterion period and that stabilization would occur sooner than 5 minutes for both LnRMSSD parameters.

Methods

Participants

Thirty-five elite futsal players (23.9 ± 4.5 y, 174.2 ± 4.0 cm, 74.0 ± 7.5 kg, 1576.2 ± 396.3 m in the Yo-Yo Intermittent Recovery Test, level 1—Yo-Yo IR1) of 3 different teams, playing one of the most important regional championships in Brazil, in distinct years, took part in this study. The Yo-Yo IR1 distance of these athletes is lower than values found in professional soccer players (>2000 m),[20] while superior to that of professional futsal players assessed in other studies (eg, ~1200 m in the study of Boullosa et al[21]). This study involved participants taking part in 3 different previous projects published by our research group.[6,22,23] Data were compiled because procedures were consistent across studies and the total number of participants provided higher statistical power to our analyses. The purpose of those studies was to verify the HRV adaptations after a standard futsal preseason period. All studies were approved by the same ethics committee.

Procedures

All HRV assessments were conducted in a single session (Monday) after 3 or 4 weeks of a standard futsal preseason (with training schedules detailed in previous studies),[6,22,23] before starting the most important competition of the year. The athletes arrived at the futsal gym for the first training session of the week, after at least 48 hours of rest from training sessions, in a fasted state for 2 hours and free of caffeine or alcohol consumption for at least 24 hours. From the total sample (N = 35), 20 players performed the HR-data collection in the morning (between 8:00 and 10:00 AM), while 15 players performed it in the afternoon (between 3:00 and 5:00 PM). This discrepancy was due to differences in team schedules.

Before data collection, athletes were provided with heart-rate monitors and chest-strap transmitters and received verbal instructions about how to proceed. Subsequently, they sat down and <1 minute was given to start HRV-data acquisition. Participants received instructions to remain quiet, with eyes open, and to breathe spontaneously[24] over the acquisition period. The seated position was standardized in a comfortable chair with backrest (~100° angle from the transverse plane corresponding to the seat), having the participants' hands resting at their thighs.

HRV Analysis

The RR-interval recordings were obtained using a portable heart-rate monitor (Polar RS800cx, Kempele, Finland)[25,26] at a sampling of 1000 Hz continuously for 10 minutes[1] in the seated position. Data were visually inspected to identify artifacts and ectopic beats (<3%), which were manually removed and replaced by interpolation of adjacent RR intervals. The RR recordings were downloaded via accompanying Polar software (Polar ProTrainer, Kempele, Finland) and exported for later analysis of time-domain measures of HRV by Kubios v2 Heart Rate Variability software (Biosignal Analysis and Medical Imaging Group at the Department of Applied Physics, University of Kuopio, Kuopio, Finland).

The 2 dependent variables analyzed were root-mean-square difference of successive normal RR intervals (RMSSD), which was transformed in LnRMSSD to avoid outliers and simplify its analysis, and LnRMSSD:RR, which was multiplied by 1000 to simplify its visualization. The LnRMSSD was expressed in milliseconds and the LnRMSSD:RR is reported without units. From the 10-minute HRV-recording period, LnRMSSD and LnRMSSD:RR were analyzed in the following time segments: (1) from 0 to 5 minutes (ie, stabilization period); (2) from 0 to 1 minute, 1 to 2 minutes, 2 to 3 minutes, 3 to 4 minutes, and 4 to 5 minutes; and (3) from 5 to 10 minutes (ie, criterion period). The 1-minute measures will be collectively labeled as ultra-short-term measures.

Statistical Analysis

Data are presented as mean and SD. To analyze differences between time periods for both LnRMSSD and LnRMSSD:RR, an analysis approach based on the effect size (ES)[27] was conducted. The magnitudes of the ES were interpreted using the thresholds proposed by Hopkins et al[28,29] as follows: trivial, <0.2; small, 0.2–0.6; moderate, 0.6–1.2; large, 1.2–2.0; or very large, >2.0. In addition, to assess the agreement between time periods for both dependent variables, the intraclass correlation coefficient (ICC) was used, interpreted using the following thresholds: 0 to .30, small; .31 to .49, moderate; .50 to .69, large; .70 to .89, very large; and .90 to 1.00, nearly perfect.[28,29] In addition, the upper and lower limits of agreement between time periods were analyzed by the Bland-Altman[30] plots.

Results

Table 1 presents the results of the LnRMSSD for the 7 time periods analyzed. Trivial to small differences were found between the last 5-minute criterion period and the other 6 time periods. In addition, the ICC analysis showed very large to nearly perfect agreement between the last 5-minute criterion period and the other 6 time periods. In addition, the limits of agreement from the Bland-Altman analysis showed relatively narrow values around a close-to-zero bias (Table 1).

Table 2 presents the results of the LnRMSSD:RR for the 7 time periods analyzed. Trivial to small differences were found between the last 5-minute criterion period and the other 6 time periods. In addition, the ICC analysis showed very large to nearly perfect agreement between the last 5-minute criterion period and the other 6 time periods. In addition, the limits of agreement from the Bland-Altman analysis showed relatively narrow values around a close-to-zero bias (Table 2).

Table 1 Comparison of Last 5-Minute LnRMSSD Analysis With the Different Time Periods

Time period	Mean ± SD (ms)	ES (95% CI), rating	ICC (95% CI), rating	Bias (± 1.96 SD)
Last 5 min	3.81 ± 0.49	—	—	—
First 5 min	3.77 ± 0.47	–0.08 (–0.24 to 0.09), trivial	.94 (.87–.97), near perfect	0.04 (–0.42; 0.50)
0–1 min	3.82 ± 0.52	0.03 (–0.18 to 0.24), trivial	.89 (.79–.95), very large	–0.02 (–0.64; 0.61)
1–2 min	3.80 ± 0.53	–0.01 (–0.21 to 0.19), trivial	.90 (.81–.95), near perfect	0.01 (–0.60; 0.61)
2–3 min	3.69 ± 0.50	–0.24 (–0.41 to –0.07), small	.92 (.84–.96), near perfect	0.12 (–0.37; 0.61)
3–4 min	3.69 ± 0.48	–0.23 (–0.44 to –0.02), small	.88 (.77–.94), very large	0.11 (–0.48; 0.70)
4–5 min	3.67 ± 0.51	–0.29 (–0.50 to –0.06), small	.86 (.73–.93), very large	0.14 (–0.50; 0.78)

Table 2 Comparison of Last 5-Minute LnRMSSD:RR Analysis With the Different Time Periods

Time period	Mean ± SD	ES (95% CI), rating	ICC (95% CI), rating	Bias (± 1.96 SD)
Last 5 min	4.38 ± 0.54	—	—	—
First 5 min	4.31 ± 0.48	–0.15 (–0.31 to 0.01), trivial	.94 (.87–.97), near perfect	0.08 (–0.40; 0.55)
0–1 min	4.33 ± 0.49	–0.10 (–0.34 to 0.15), trivial	.85 (.71–.92), very large	0.05 (–0.68; 0.78)
1–2 min	4.26 ± 0.52	–0.23 (–0.44 to –0.02), small	.88 (.77–.94), very large	0.12 (–0.52; 0.77)
2–3 min	4.20 ± 0.57	–0.32 (–0.47 to –0.17), small	.92 (.84–.96), near perfect	0.18 (–0.32; 0.68)
3–4 min	4.29 ± 0.55	–0.17 (–0.37 to 0.04), trivial	.89 (.78–.94), very large	0.09 (–0.57; 0.75)
4–5 min	4.22 ± 0.49	–0.31 (–0.54 to –0.08), small	.84 (.68–.92), very large	0.16 (–0.53; 0.86)

Discussion

The main findings of this study were that (1) LnRMSSD and LnRMSSD:RR values obtained during the stabilization period (ie, 0–5 min) were not different from (ie, trivial ES) and had very large to nearly perfect ICCs with the values obtained during the criterion period (ie, 5–10 min) and (2) in the ultra-short-term analysis (ie, 1-min segments within 0–5 min) the data showed slightly less accurate results, but only trivial to small differences with very large to near perfect ICCs were found, suggesting good levels of agreement with the criterion. These results are in agreement with our hypothesis that the analysis of the 5 minutes of stabilization would not differ from the criterion. In addition, in the ultra-short-term measures, the ES, ICC, and Bland-Altman analyzed together demonstrated acceptable levels of agreement and association with the criterion from the first to the fifth minute of analysis. Finally, the lowest ICC (.86) found between ultra-short-term measures and criterion was within the 95% CI of the highest ICC (.92).

The desire for more convenient HRV-recording methodology is evidenced by recent investigations assessing the suitability of shorter and more-convenient measurement procedures in athletic,[13,14,31,32] nonathletic,[7,17] and clinical populations.[16] The results of the current study are in accordance with a recent report by Flatt and Esco,[14] who found no difference, trivial ESs, and nearly perfect ICCs in 60-second LnRMSSD segments derived from the stabilization period compared with the criterion among 20 endurance athletes from supine ECG measures.

The ultra-short-term analysis (1 min) also demonstrated good levels of agreement with the criterion period. Similar results were found by Esco and Flatt,[13] showing that the analysis of randomly selected, 1-minute segments from the criterion is a reliable time frame to derive LnRMSSD from supine measures in college team-sport athletes. Although the levels of agreement were not as high in the analysis of the stabilization period here, the results of the current study suggest that the analysis of only a 1-minute recording, chosen from the stabilization period, would be acceptable, mainly when time constraints are present.

Traditional 10-minute HRV-recording methodology makes frequent data collection very difficult in field settings.[32,33] In addition to shorter measurement durations, investigation into more-user-friendly HRV field tools such as smart phone applications[31,34] and reduced measurement frequency to 3 to 5 d/wk[32] all contribute to increasing the practicality of HRV monitoring in athletes. Collectively, the available research suggests that for LnRMSSD assessment in athletic individuals, a traditional 5-minute stabilization period is likely not necessary under resting conditions. In addition, when 5-minute recording periods are not possible due to time constraints, ultrashort measures of 1 minute may suffice after <1 minute of stabilization when seated or supine. The main limitation of the current study is that training status was not evaluated. Therefore, further studies assessing the efficacy of 5-minute and ultrashort measures without a traditional stabilization period for reflecting training status over acute and longitudinal training are required.

To conclude, the data presented herein indicate that field measures of LnRMSSD and LnRMSSD:RR can be recorded in 5 minutes without traditional stabilization periods under resting conditions in team-sport athletes. The analysis of the 0- to 5-minute segment demonstrated high levels of agreement with the criterion.

The ultra-short-term analysis (ie, 1 min within the stabilization period) also revealed acceptable levels of agreement with the criterion, although not as strongly as the full 5-minute segment. It is strongly suggested that ultrashort measures can be an adequate alternative when 5-minute periods are not possible or risk compliance problems with athletes.

Practical Applications

Reducing the time to assess the HRV in elite team-sport athletes can help conditioning trainers and coaches implement this strategy to monitor/assess training load and physical adaptations in their athletes. Shortened HRV-recording procedures may alleviate compliance problems with athletes and enable more-frequent monitoring. Valuable time for coaches and athletes can be saved by reducing the recording procedures to 5 minutes or less. This study yielded an important finding that improves the convenience of HRV assessment and makes implementation more practical in field settings. Based on the results, we suggest that after heart-rate-monitor fitting and accommodation in the seated position (<1 min), 2 minutes of RR-interval recording (1 min stabilization and 1 min of actual analysis) is sufficient to obtain acceptable (ie, good levels of agreement) LnRMSSD and LnRMSSD:RR in comparison with the respective criterion measures.

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