



## Adequacy of the Ultra-Short-Term HRV to Assess Adaptive Processes in Youth Female Basketball Players

by

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*Heart rate variability has been widely used to monitor athletes' cardiac autonomic control changes induced by training and competition, and recently shorter recording times have been sought to improve its practicality. The aim of this study was to test the agreement between the (ultra-short-term) natural log of the root-mean-square difference of successive normal RR intervals (lnRMSSD - measured in only 1 min post-1 min stabilization) and the criterion lnRMSSD (measured in the last 5 min out of 10 min of recording) in young female basketball players. Furthermore, the correlation between training induced delta change in the ultra-short-term lnRMSSD and the criterion lnRMSSD was calculated. Seventeen players were assessed at rest pre- and post-eight weeks of training. Trivial effect sizes (-0.03 in the pre- and 0.10 in the post- treatment) were found in the comparison between the ultra-short-term lnRMSSD ( $3.29 \pm 0.45$  and  $3.49 \pm 0.35$  ms, in the pre- and post-, respectively) and the criterion lnRMSSD ( $3.30 \pm 0.40$  and  $3.45 \pm 0.41$  ms, in the pre- and post-, respectively) (intraclass correlation coefficient = 0.95 and 0.93). In both cases, the response to training was significant, with Pearson's correlation of 0.82 between the delta changes of the ultra-short-term lnRMSSD and the criterion lnRMSSD. In conclusion, the lnRMSSD can be calculated within only 2 min of data acquisition (the 1<sup>st</sup> min discarded) in young female basketball players, with the ultra-short-term measure presenting similar sensitivity to training effects as the standard criterion measure.*

**Key words:** team sports, youth athletes, body position, vagal activity, court sports.

### Introduction

Team sports athletes are regularly exposed to high training and game loads aimed at improving their physical capacities and on-court skills. When adequately applied, this routine leads to several physiological adaptations over the course of a season, enhancing both neuromuscular and cardiovascular fitness components (Mohr and Krstrup, 2014; Oliveira et al., 2013). The improvement in vagal cardiac-autonomic control, as measured by heart rate variability (HRV), has been associated with increments in aerobic performance and seems to be an important pre-requisite to enable athletes to

cope with training demands (Buchheit et al., 2010, 2012; De Freitas et al., 2015; Flatt and Esco, 2015a). Conversely, a progressive reduction in vagally-mediated HRV indices (e.g., the natural log of the root-mean-square difference of successive normal RR intervals (lnRMSSD)) may be indicative of maladaptation and/or a decrease in performance (Pichot et al., 2002; Plews et al., 2013). Thereby, the frequent use of HRV (e.g., on a daily basis) may be a very useful strategy for monitoring the athletes' functional status and, consequently, for guiding coaches and sport scientists in adjusting the training loads throughout the preparation and

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competitive periods (Buchheit, 2014; Flatt and Esco, 2015a).

Despite its relative simplicity and validity, the main shortcoming related to daily assessment of HRV is the time-consuming nature of the procedures. According to the Task-Force (1996), obtaining HRV indices should involve a 5 min stabilization period in a quiet position before undertaking a 5 min period of actual recording, which is considered the criterion (i.e., minutes 5-10). Alternatively, recent research has demonstrated excellent agreement between selected 1 min lnRMSSD values within the stabilization period and those obtained during the criterion period (5 min) among athletes using standard electrocardiograph (ECG) recordings and portable heart rate monitors (Esco and Flatt, 2014; Flatt and Esco, 2015b; Nakamura et al., 2015; Pereira et al., 2015). The 1-2 min period within the stabilization phase was the measure with greatest agreement with the criterion measure (Pereira et al., 2015) and its delta change was highly correlated with the change in the criterion in response to training (Nakamura et al., 2015). These results permit shortening the data acquisition (to 2 min) and may facilitate daily HRV assessments, especially because it has been shown that multiple weekly measures are necessary to obtain more reliable and valid measures from athletes in order to detect training adaptations (Flatt and Esco, 2015a; Plews et al., 2014).

Although the agreement between the ultra-short-term HRV (i.e., 1 min lnRMSSD) and criterion 5 min data acquisition has been previously demonstrated (mostly in adult men) (Esco and Flatt, 2014; Flatt and Esco, 2015b), studies involving different sports disciplines and populations (i.e., young female basketball players) are warranted in order to extend its use. Additionally, it remains to be established whether the so-called ultra-short-term lnRMSSD measured in 1 min epochs into the stabilization period is as sensitive to team sports training effects as the lnRMSSD derived from criterion procedures. The only previous evidence (Nakamura et al., 2015) showed that the ultra-short-term lnRMSSD was as sensitive as the criterion lnRMSSD to detect changes in the cardiac autonomic regulation in response to futsal training in male adult athletes. Since it is known that male and female athletes

may differ in HRV indices in both cross-sectional and longitudinal training studies (Berkoff et al., 2007; Schafer et al., 2015), it remains to be established whether the ultra-short-term HRV is sensitive to training effects and can be used to monitor female team sports athletes.

Therefore, the objectives of this study were twofold: 1) to test the agreement between ultra-short-term lnRMSSD obtained in two different training cycles and the respective criterion and; 2) to investigate whether the change in ultra-short-term lnRMSSD was significantly correlated with the change in the criterion lnRMSSD, in young female basketball players. Independent of the training cycle and the absolute values of lnRMSSD, we hypothesized that the ultra-short-term HRV (measured in only 1 min post-1-min stabilization) would be similar to the criterion (5 min measure post-5 min stabilization). Moreover, it was expected that the delta changes in ultra-short-term lnRMSSD would be similar and significantly correlated to delta changes in the criterion lnRMSSD.

## **Material and Methods**

### *Participants*

Seventeen young female basketball players ( $16.5 \pm 1.2$  years;  $178.6 \pm 8.1$  cm;  $73.4 \pm 15.2$  kg;  $6.6 \pm 2.2$  years of training experience), participating in under 17 (U17) and under 19 (U19) categories of basketball took part in this study. The basketball teams were respectively involved in the most important youth State level competitions in Brazil and 7 athletes were part of the national team. The study was approved by the Ethics Committee of the Bandeirantes Anhanguera University and all subjects and their legal guardians were informed of the inherent risks and benefits of the study before signing an informed consent form.

### *Procedures*

All HRV assessments were conducted pre- and post-eight weeks of a standardized training cycle (involving 8 weeks of training with no official matches). Both U17 and U19 teams performed the same training schedule during this period and were assessed together. Training consisted of 3 conditioning sessions (strength/power and endurance), and 5 technical-tactical training sessions per week. In addition, the U17 team played 4 friendly games, while the

U19 played only 2 friendly games during the observation period. The HRV data from both teams were similar in the pre- and post-periods. Therefore, in order to improve the statistical power of the analyses, we opted to present the pooled results. The pre- and post-training HRV measures were recorded at the same hour, seated on a bench, in the training facilities (basketball court). The athletes arrived at the basketball gym for the first training session of the week, after  $\approx$  48 h of rest from the last training session, in a fasted state for 2 h and free of caffeine or alcohol consumption for at least 24 h.

Prior to data collection, athletes were provided with the previously moistened chest strap transmitters which were firmly fitted to the chest (over the xiphoid process), and received verbal instructions about the procedures. Subsequently, athletes sat down and were given  $<1$  min to check for the functioning of the receiver for RR intervals acquisition. Participants received instructions to remain quiet, with eyes opened, and to breathe spontaneously (Bloomfield et al., 2001) over the acquisition period.

#### **HRV analysis**

The RR interval recordings were obtained using a portable heart rate monitor (Polar® ProTrainer, Kempele, Finland) at a sampling rate of 1,000 Hz, continuously for 10 min (Gamelin et al., 2006; Task-Force, 1996; Wallen et al., 2012). 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) (Tarvainen et al., 2014). Occasional artifact noise was automatically replaced with the interpolated adjacent RR interval values (filter power  $<$ low).

The dependent variable analyzed was the lnRMSSD (and not the non-transformed RMSSD) to avoid outliers, simplify its analysis and due to it being preferred for athlete monitoring (Buchheit, 2014; Plews et al., 2013). This variable was expressed in milliseconds. From the 10 min HRV recording period, lnRMSSD was analyzed in the following time segments: 1) 1-2 min; and 2) from 5-10 min (i.e., criterion period). The 1 min measure (1-2 min) was considered the ultra-short-

term measure.

#### **Statistical Analysis**

Data is presented as means and standard deviations (SD). An analysis approach based on the effect size (ES) (Cohen, 1988) was used to evaluate differences between both time periods of lnRMSSD. The magnitudes of the ES were interpreted using the thresholds proposed by Hopkins et al. (2009) as follows: trivial ( $<0.2$ ), small (0.2-0.6), moderate (0.6-1.2), large (1.2-2.0) or very large ( $>2.0$ ). Also, to assess the agreement between the ultra-short-term and criterion lnRMSSD, the intra-class correlation coefficient (ICC) was applied, interpreted using the following thresholds: 0 to 0.30 (small), 0.31 to 0.49 (moderate), 0.50 to 0.69 (large), 0.70 to 0.89 (very large) and 0.90 to 1.00 (near perfect) (Hopkins et al., 2009). In addition, the upper and lower limits of agreement between the time periods (1 min vs 5 min) were analyzed by the Bland and Altman (1986) plots.

To analyze differences between the pre- and post- periods for lnRMSSD, the differences based on magnitudes (Batterham and Hopkins, 2006) were calculated. The quantitative chances for the post- measures having higher, similar or lower values than pre- measures, using a smallest worthwhile change (SWC) of 3% (Buchheit, 2014) and a confidence interval (CI) of 90%, were assessed qualitatively as follows:  $<1\%$ , almost certainly not; 1 to 5%, very unlikely; 5 to 25%, unlikely; 25 to 75%, possible; 75 to 95%, likely; 95 to 99%, very likely;  $>99\%$ , almost certain. If the chances of having better and poorer results were both  $>5\%$ , the true difference was assessed as unclear. Finally, the correlations of the percentage of differences ( $\Delta\%$ ) between the ultra-short-term period of analysis (1 min) and criterion (5 min) were analyzed using the Pearson test. The threshold used to qualitatively assess the correlation was based on Hopkins et al. (2009), using the following criteria:  $<0.1$ , trivial; 0.1 – 0.3, small; 0.3 – 0.5, moderate; 0.5 – 0.7, large; 0.7 – 0.9, very large,  $>0.9$ , nearly perfect. The level of significance was set at  $p < 0.05$ .

## **Results**

Table 1 shows the comparisons and the agreement of the lnRMSSD between the ultra-short-term (1 min) and the criterion (5 min) analysis at the pre- and post- treatment, in youth

female basketball players. The difference was rated as *trivial* and the ICC between the ultra-short-term and criterion lnRMSSD was *nearly perfect* in both moments.

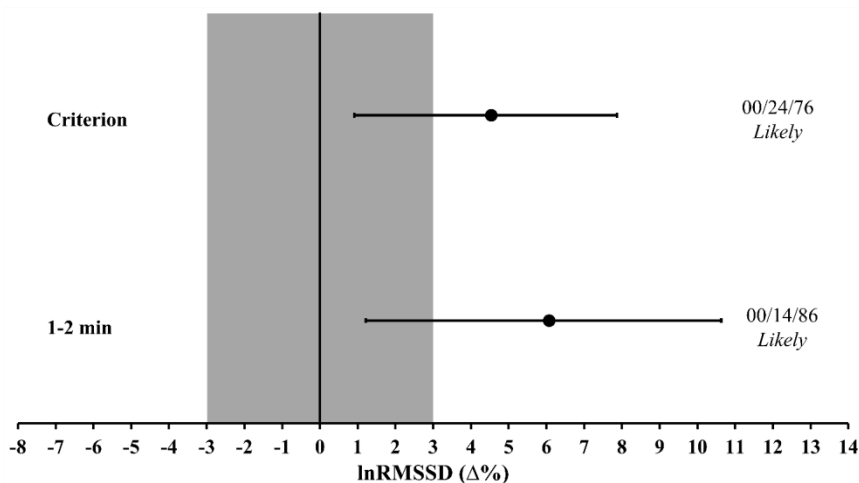
Figure 1 depicts the percentage of change in the lnRMSSD from pre- to post- treatment for both periods of analysis. Both the ultra-short-term

(1 min) and the criterion (5 min) measures showed a significant improvement.

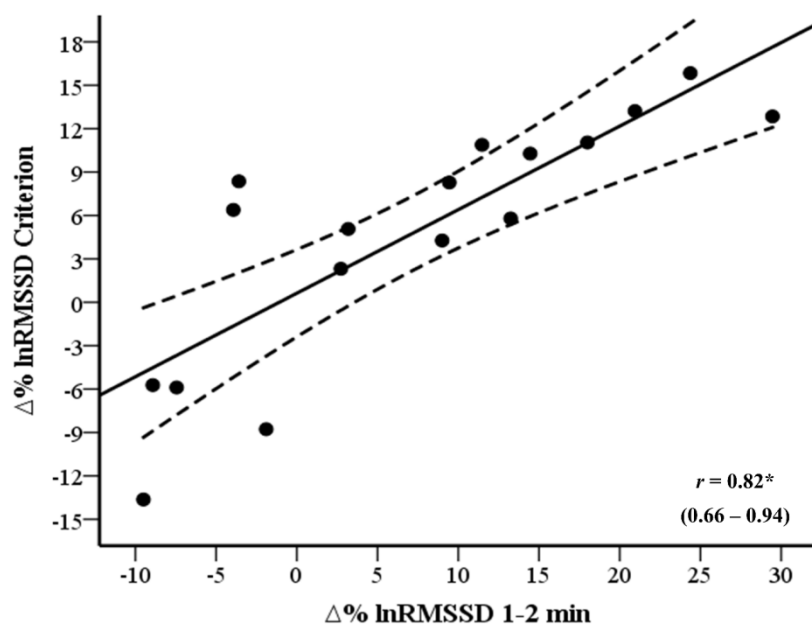
Figure 2 displays the correlation between delta changes in the ultra-short-term (1-2 min) and the criterion in response to training. A *very large* correlation ( $r = 0.82$ ) was found.

**Table 1**  
Comparison of the lnRMSSD between criterion (5 min) and the ultra-short-term (1 min) of analysis at pre and post treatment.

Time period		Mean $\pm$ SD (ms)	ES (95% CI) Rating	ICC (95% CI) Rating	Bias ( $\pm 1.96 \cdot SD$ )
Pre	Criterion	3.30 $\pm$ 0.40	–	–	–
	1-2 min	3.29 $\pm$ 0.45	-0.03 (-0.70 – 0.65) <i>Trivial</i>	0.95 (0.85 – 0.98) <i>Near Perfect</i>	0.01 (-0.37 – 0.39)
Post	Criterion	3.45 $\pm$ 0.41	–	–	–
	1-2 min	3.49 $\pm$ 0.35	0.10 (-0.57 – 0.77) <i>Trivial</i>	0.93 (0.82 – 0.97) <i>Near Perfect</i>	-0.04 (-0.42 – 0.34)



**Figure 1**  
Percentage of change ( $\Delta\%$ ) of the lnRMSSD between pre- and post- moments in young female basketball players. The bars represent the 90% confidence interval, and the grey rectangle represents the smallest worthwhile change (3%).



**Figure 2**

Correlations (95% CI) of the percentage of change ( $\Delta\%$ ) in the  $\ln\text{RMSSD}$  between the ultra-short-term (1 min) and the criterion (5 min). \* $p < 0.01$ .

## Discussion

It has been previously reported that female professional basketball players show cardiac autonomic adaptations in response to training favoring the parasympathetic activity as inferred from changes in spectral analysis indices (Messina et al., 2012). However, to the best of our knowledge, this is the first study showing that the change in heart rate variability using the ultra-short-term  $\ln\text{RMSSD}$  (1 min period) after only 1 min of RR interval stabilization is as sensitive as the criterion (5 min) measure, which demands 10 minutes of quiet data acquisition in the same body position (e.g., seated position). Additionally, we confirmed previous findings (Esco and Flatt, 2014; Flatt and Esco, 2015b; Pereira et al., 2015) reporting that the ultra-short-term  $\ln\text{RMSSD}$  presented high levels of agreement (low bias/narrow limits of agreement in the Bland-Altman plot and near perfect ICC (0.93 and 0.95) with criterion  $\ln\text{RMSSD}$ ), but this time in two

different training periods with distinct vagal-related activity as measured by criterion HRV, in youth female basketball players.

Previously, comparable levels of agreement were reported between ultra-short-term  $\ln\text{RMSSD}$  and criterion  $\ln\text{RMSSD}$  in studies involving cross-country runners (Flatt and Esco, 2015b), male college team sports players (Esco and Flatt, 2014) and professional futsal players (Pereira et al., 2015). In the only study involving females (Flatt and Esco, 2015b), performed in the supine position, gender was not taken into account and these participants were pooled with male counterparts to compose the investigated group. Therefore, it was uncertain if youth female team-sport players (i.e., basketball) would present high levels of agreement between their ultra-short-term  $\ln\text{RMSSD}$  and criterion measure. Nevertheless, we expected to find acceptable values of agreement between the methods to calculate the  $\ln\text{RMSSD}$  due to previous findings showing similar relative (ICC) and absolute

(typical error of measurement) reproducibility of RMSSD between young males and females (Sookan and Mckune, 2012). Our results confirmed this hypothesis.

More importantly, in spite of the differences observed in the absolute values at pre- and post- treatment, high levels of agreement between the ultra-short-term lnRMSSD (collected in the 1-2 min window) and the criterion lnRMSSD (5 min) were found in both assessments. This result suggests that the accuracy of the ultra-short-term method is not affected by the eventual changes in lnRMSSD, which extends previous findings (Nakamura et al., 2015; Pereira et al., 2015). In other team sports, vagally-mediated HRV is changed on a daily basis. For instance, HRV is slightly reduced in volleyball players prior to play-offs, which is possibly due to anxiety and arousal (D'ascenzi et al., 2014). It remains to be established whether ultra-short-term recordings are sensitive enough to detect such slight changes, besides the more pronounced alterations regarded to training load variations (Flatt and Esco, 2015a). Nevertheless, the ultra-short-term method can substantially enhance the practicality of HRV measures in field conditions as the measures in this study were undertaken in the training facilities (on a bench located in the training gymnasium and not in a controlled laboratory environment, meaning high ecological validity).

The female basketball players investigated here significantly improved the criterion lnRMSSD (from 3.30 to 3.45 ms). The 0-1 min period was used to quickly stabilize the RR values, after accommodation to the seated position and fitting the chest straps transmitters. Therefore, this period was not addressed in the analysis and we recommend discarding the data and only utilizing this period for the purpose of stabilization, since we have recently shown that the 1-2 min window presented the greatest agreement with the criterion measure and its delta change was the most highly correlated (Spearman  $\rho$  correlation = 0.75) to the change in the criterion in response to training (Nakamura et al., 2015; Pereira et al., 2015). In this study, we reinforced this evidence showing that the 1-2 min window provided significant delta change between pre- and post- treatment, with absolute values similar to the criterion (from 3.29 to 3.49 ms). Finally,

recent studies have shown the need of assessing HRV on daily basis (or at least 3 times per week), to obtain a weekly average (Plews et al., 2012, 2013, 2014). In future studies, the ultra-short-term HRV usefulness on a daily basis should be tested in order to facilitate the use of HRV by coaches and athletes.

The very large correlation ( $r = 0.82$ ) between changes in the ultra-short-term and the criterion lnRMSSD measure demonstrates that 1 min of stabilization followed by 1 min of analysis appears to be a valid approach to quantify the adaptations in the former. This is in agreement with the results found in professional male futsal players (Nakamura et al., 2015), and reinforces the practical suggestion of using this time window (1-2 min) to monitor athletes' cardiac autonomic activity and adjust the training loads accordingly.

This study is limited by the assessment of "isolated" lnRMSSD measures, as recent studies have suggested the need of using multiple measures per week to more reliably assess the responses of the cardiac autonomic system to the training loads (Plews et al., 2013, 2014). However, it is proposed that our results may help coaches implement the daily assessments by shortening the RR interval acquisition. In practice, ultra-short-lnRMSSD procedures facilitate more frequent monitoring due to less time requirements from athletes compared to traditional methodology and thus, enhance the practical usefulness of this tool in the field. More frequent data collection of lnRMSSD enables coaches to more effectively guide programming for athletes by manipulating training loads (Kiviniemi et al., 2007), detect fatigue and overreaching (Le Meur et al., 2013; Plews et al., 2012), evaluate training adaptations (Boullosa et al., 2013); and assess recovery status from training and competition (Bricout et al., 2010; Edmonds et al., 2013). Lastly, in the present study the relationship between the lnRMSSD and its delta changes was not correlated with changes in physical performance. This issue deserves further investigation.

## Conclusion

To conclude, lnRMSSD can be calculated within only 2 min of data acquisition in youth female basketball players. The first minute of HRV data should be discarded, as this time period should only be utilized for stabilization. The

following minute of data acquisition in the seated position will provide an lnRMSSD value, which is comparable to the criterion measure (i.e., 5 min period, after 5 min stabilization). In addition, this ultra-short-term measure presents delta change in

response to training which is comparable and very largely correlated to the change in the criterion lnRMSSD. This fact permits monitoring cardiac autonomic adaptations using a simple and easy to apply measure in female team sports athletes.

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