

The Effects of Heart Rate Versus Speed-Based High-Intensity Interval Training on Heart Rate Variability in Young Females

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Abstract

Introduction: The aim of this study was to compare the effects of high-intensity interval training (HIT) prescription by heart rate (HR-based) and running speed (speed-based) methods on natural logarithm of the square root of the mean of the sum of the squares of differences between adjacent normal R-R intervals (Ln rMSSD) as a measure of heart rate variability (HRV) in young female student athletes.

Methods: Seventeen female student athletes participated in this study and were divided into HR-based (n=9, age: 16.7 years) and speed-based (n=8, age: 16.9 years) HIT groups. 30-15 Intermittent Fitness Test was used for the speed-based group to detect the reference maximum speed (V_{IFT}) for prescribing the HIT intensity accordingly. Age predicted maximal HR was used for the HR-based group as the reference value. All subjects performed similar training protocol for 5 weeks, except the method of individualizing HIT sessions (2 weekly sessions of HIT=3 sets of 3 minutes work interspersed with 3 minutes passive recovery with the 15-15 seconds format during each working set); either according to 90%-95% of maximal HR or V_{IFT} .

Results: HR- and speed-based HIT groups showed the most likely large improvements in Ln rMSSD of +7.9%, 90% confidence limits [CL] (5.9; 10.0); standardized change: +1.75 (1.32; 2.19) and +5.5%, (2.8; 8.3); +1.41 (0.72; 2.09), respectively. In between group analyses, HR-based HIT produced likely a small greater improvement in Ln rMSSD than speed-based HIT (+1.9%, [-5.0; 4.4]; +0.50 [-0.14; 1.14], chances for greater/similar/lower values of 79/17/4).

Conclusion: It is concluded that both HIT prescription strategies were effective in Ln rMSSD elevation, but using maximal HR as a reference may elicit higher parasympathetic dominance with small effect in young female student athletes.

Keywords: Heart Rate, High-intensity interval training, Fitness, Heart rate variability, Females

Introduction

Heart rate variability (HRV) is referred to a measure of interactions between sympathetic and parasympathetic nervous systems or a general marker of autonomic function.¹ HRV, in brief, is derived from the mathematical properties of cardiac inter-beat intervals (i.e. R-R interval).¹ The importance of HRV has been highlighted in the literature by its relationship with several diseases and conditions.²⁻⁴ Furthermore, HRV is known as a risk factor for all-cause mortality.⁵ It has also been shown that different training interventions particularly high-intensity interval training (HIT) can

improve HRV profile in both patient and athletes' populations by enhancing parasympathetic dominance.^{4,6-9}

When individualizing HIT programs, different variables including the training intensity need to be taken into account.^{10,11} Accordingly, the use of maximal heart rate (HR_{max}) or the final speed reached in 30-15 Intermittent Fitness Test ($30-15_{IFT}$, V_{IFT}) as a reference, are two approaches known as HR-based and speed-based methods, respectively.¹⁰ Although HR-based method has several proposed limitations including difficulties for practitioners when controlling exercise intensity, it is yet the most

common method implemented in the field.¹⁰ Furthermore, there are a number of proposed theoretical superiorities of speed-based HIT by using V_{IFT} as a reference over the HR-based methods including its higher sensitivity to the athlete's locomotor profile, acceleration, deceleration, and change of direction abilities.¹² It has also been shown that V_{IFT} -based method is more effective than HR-based HIT to improve maximal high-intensity running performance among the athletes.¹³ However, differences between these two approaches (i.e., speed-based vs. HR-based) in improving the physiological adaptations like HRV have not been investigated yet.

In addition, while analyzing HRV includes a myriad of variables in three different aspects (i.e., time domain, frequency domain and spectral analyses), the use of the square root of the mean of the sum of the squares of differences between adjacent normal R-R intervals (Ln rMSSD) has been recommended as a valid and sensitive marker for monitoring training-induced physiological adaptations in athletes.¹⁴ Fortunately, advancements in smart phone apps have recently provided ultra-short-time Ln rMSSD as a valid index.¹⁵ However, while it has been shown that ultra-short-time Ln rMSSD, is sensitive to team sport training interventions,¹⁶ the differences between the effects of different HIT protocols on this marker have yet to be determined.

Following these lines, there seems to be a lack of evidence on differences between the effects of HR-based and speed-based HIT interventions on ultra-short-time Ln rMSSD in the literature. Therefore, the purpose of this study was to investigate the within group changes and between group differences in changes of ultra-short-time Ln rMSSD following 5 weeks of speed-based and Heart-based HIT interventions in young female student athletes.

Methods

Subjects

Seventeen female student athletes participated in this quasi-experimental study and were divided into HR-based ($n=9$, mean \pm SD; age: 16.7 ± 0.3 years, weight: 59.8 ± 2.6 kg, height: 162.4 ± 2.7 cm) and speed-based ($n=8$, age: 16.9 ± 0.3 years, weight: 58.7 ± 3.2 kg, height: 164.3 ± 3.3 cm) HIT groups. Before the study, pre levels of resting HRV were used to allocate the participants in 2 homogenous experimental groups. First explanations about the experimental risks of the study were given and later informed consent was obtained from all the participants and their parents. Furthermore, local research eth-

ics committee approved the protocol and the study conformed to the Declaration of Helsinki.¹⁷

Testing and Training

The speed-based group performed 30-15_{IFT}¹² before HIT intervention. 30-15_{IFT} is an incremental high-intensity intermittent running performance field test. The final speed derived from this test (i.e., V_{IFT}) is a reference to individualize speed-based HITs.¹⁸ 30-15_{IFT} was performed at the same time of day (10 AM) with similar temperature ranging between 26°C to 28°C. The intensity in both groups was individualized to train the subjects in their red zone (i.e., >90% HR_{max}). Age predicted HR_{max} was used for the HR-based group as the reference value.¹⁹ Participants in the HR-based group had to check the Polar Beat™ application installed on their smart-phone regularly during HIT sessions while using a HR Bluetooth sensor (Polar H7, Finland) to assure exercising in the prescribed zone. The individualized running pace using V_{IFT} has been calculated for each subject in the speed-based group. All V_{IFT} -based subjects were guided to set their running pace according to an audio signal. While it was not mandatory for the HR-based group to set their running speed according to auditory signal, the running speed for the V_{IFT} -based group was adjusted according to maximal test speed explained in detail previously.¹³ The experimental period lasted for 5 weeks with 2 weekly HIT sessions. The training protocol during the entire experimental period is shown in Table 1.

Heart Rate Variability Recording

Home based resting ultra-short-term HRV recording was asked from all subjects in both groups.¹⁶ The subjects were asked to collect HRV using HRV application installed on their smart phones using HR Bluetooth sensor (H7, Polar, Finland) around fastened their trunk near to xiphoid area as well according to the previous investigations guidelines.¹⁶ The subjects were guided to record their HRV in the morning before eating and in the supine position. The R-R intervals derived from Elite HRV™ smart phone application were exported to be analyzed later by Kubios HRV software to calculate Ln rMSSD.²⁰ Weekly averages of Ln rMSSD for the first and last week of training intervention were used as pre and post values for statistical analyses.

Statistical Analyses

Data in the figures are shown as means with 90% of CI in

Table 1. Training Program

Week	Protocol	HR-Based Intensity	V_{IFT} -Based Intensity
1	3 sets (6 reps of 15"-15" HIT)	85-90% HR max	90% V_{IFT}
2	3 sets (6 reps of 15"-15" HIT)	85-90% HR max	90% V_{IFT}
3	3 sets (8 reps of 15"-15" HIT)	90-95% HR max	95% V_{IFT}
4	3 sets (8 reps of 15"-15" HIT)	90-95% HR max	95% V_{IFT}
5	4 sets (6 reps of 15"-15" HIT)	90-95% HR max	95% V_{IFT}

Note: In all HIT (high-intensity interval training) sessions, work periods were interspersed with 3 min of passive recovery.

the case. All data were first log-transformed to reduce bias arising from non-uniformity error. Within-group changes and between-groups differences in changes of Ln rMSSD were analyzed. The percentage changes and standardized differences or effect size (ES) with 90% confidence limits (CL) were used to express the results.²¹ The Hopkins scale was used for standardized change/difference interpretation: < 0.2: Trivial; 0.2 – 0.6: Small; 0.6 – 1.2: Moderate; > 1.2: Large. Magnitude-based inference approach was used to analyze the chance that the true changes were clear or trivial.²² Probabilities were also calculated to establish whether the true changes/differences were lower than, similar to, or higher than the smallest worthwhile changes/differences (SWC, $0.2 \times$ between-subjects SD).²¹

Results

Weekly average of Ln rMSSD values are shown in Table 2. Within-group analyses showed that subjects in the HR-based and V_{IFT} -based groups had the most likely large improvements in Ln rMSSD of +7.9%, 90% CL (5.9; 10.0); standardized change: +1.75 (1.32; 2.19) and +5.5%, (2.8; 8.3); +1.41 (0.72; 2.09), respectively (Figure 1A). In between group analyses, HR-based HIT produced likely a small greater improvement in Ln rMSSD than speed-based HIT (+1.9%, 90% CL [-5.0; 4.4%]; standardized difference: +0.50 [-0.14; 1.14], chances for greater/similar/lower values of 79/17/4) (Figure 1B).

Discussion

The aim of the present study was to quantify and compare the respective effects of two methods of individualizing HIT on HRV (i.e., using percentages of either HR_{max} or the maximum speed reached during the 30-15 $_{IFT}$ (V_{IFT}^{max} as a reference value) for the first time. The main result is that while both methods allowed for substantial gains in HRV after 5 weeks, the HR-based approach produced likely a small greater improvement in Ln rMSSD compared with the speed-based approach. These results show that using the HR for individualizing HIT in young female students might be a more efficient choice to develop HRV.

Increases of Ln rMSSD suggest the increased vagal tone activity, parasympathetic dominance and in general the HRV improvement.^{9,14} Although the mechanisms responsible for vagal tone increase are not yet cleared, the angiotensin II and nitric oxide (NO) are potential mediators. Angiotensin II is known as an inhibitor of cardiac vagal tone.²³ The suppression of angiotensin II expression by training has been addressed by Buch et al.²⁴ Documented low levels of angiotensin II inferred from lower levels of plasma renin,²⁵ has been referred to be responsible, at least in part, for the higher cardiac vagal tone in athletes. Therefore, there is a possibility of increased cardiac vagal tone activity due to the training-induced suppression of angiotensin II.²⁴ The result of our study, confirming the beneficial effect of HIT interventions on Ln rMSSD, is in line with previous investigations reporting the positive outcomes^{4,6-8} and in contrast with studies showing unchanged values in HRV.^{26,27} Discrepancies between

Table 2. Weekly Average of Heart Rate Variability

Groups	Pre-test	Post-test
HR-based HIT	3.15 ± 0.13	3.40 ± 0.12
V_{IFT} -based HIT	3.17 ± 0.11	3.34 ± 0.09

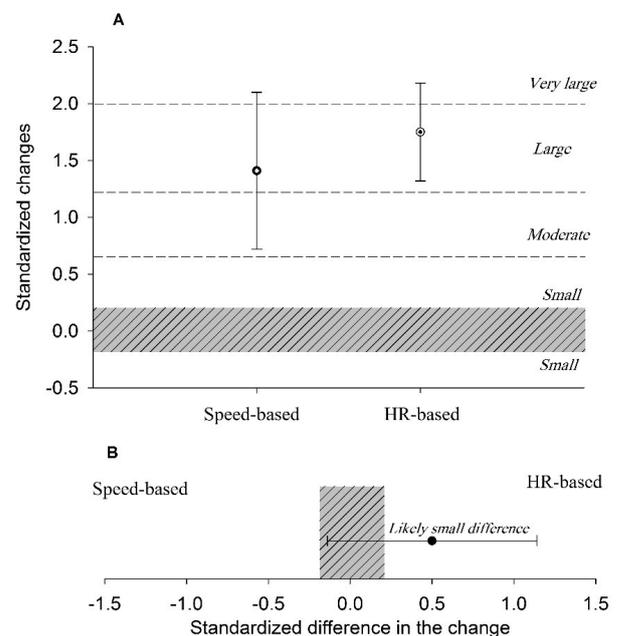


Figure 1. Training-Induced Standardized Changes (90% CI) in Heart Rate Variability of Speed-Based and HR-Based Groups (A) and Standardized Differences Between Changes (90% CI) (B).

the present study result and previous unchanged HRV reports might be due to the subjects' characteristics²⁷ or health conditions.²⁶ In fact, in the studies of Currie et al²⁶ and Gamelin et al²⁷ the subjects had coronary artery disease and were prepubescent children, respectively. While the subjects undergoing HIT intervention in the present study were healthy young females.

The interesting finding of the present study when analyzing between group differences in changes was the superiority of HR-based method in improving Ln rMSSD which showed likely a small effect. In fact, V_{IFT} has been shown to be related not only to the maximal oxygen uptake (VO_{2max}), but also to the athlete's locomotor profile (i.e., maximal sprinting speed, anaerobic speed reserve, change of direction, acceleration and deceleration).¹² It seems that HR-based approach targets mainly VO_{2max} and accordingly elicits higher cardiac related physiological adaptations including HRV.²⁸

Although speed-based HIT method is an easier method of controlling the intensity in practice, it may have lower longitudinal practicality for over loading the athlete. In fact, HR-based approach ensures that red zone (>90% of maximal HR) is always targeted during any HIT session. However, when using speed-based approach, there is not clear perspective on how athlete has been improved in terms of general fitness or V_{IFT} .²⁹ Therefore, there was not any assurance of accurate over loading the athletes and

training them in their red zones in the last weeks of the plan which may explain less improvement of a physiological marker like HRV in speed-based group.

There is just one similar study in which the effects of these 2 HIT interventions on performance improvement have been compared and the superiority of speed-based approach has been suggested which is different from our study result showing the more effectiveness of HR-based method on HRV.¹³ However, Rabbani and Buchheit¹³ used performance marker (high-intensity running performance) as the training outcome different from our study in which, physiological marker (HRV) was used. Moreover, the limitation of not training both experimental groups in similar time frame in the previous study may further explain such discrepancies.¹³

Conclusion

This study showed that both speed- and HR-based HIT methods can enhance HRV after 5 weeks in young female student athletes. However, a small greater cardiac physiological adaptation may be elicited when using HR-based approach due to its specificity.

Ethical Approval

Local ethical committee of Sport Sciences College in the University of Isfahan approved the study protocol as a master proposal in 2016.

Competing Interests

Authors declare that they have no potential conflict of interest.

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