Day-to-day variations in heart rate responses to a submaximal stationary run in young soccer players

Alireza Rabbani [1], **Martin Buchheit** [2], **Mehdi Kargarfard** [1]

[1]Department of Exercise Physiology, Faculty of Sport Sciences, University of Isfahan, Isfahan, Iran, and [2]Performance Department, Paris Saint Germain, Saint-Germain-en-laye, France

Variability | Heart-rate | Running | Soccer

Headline

The regular monitoring of athletes' training status has multiple benefits, including training load optimization, injury risk reduction and fitness enhancement/maintenance (1). Hear rate measures collected from submaximal tests are among the most useful markers for monitoring purposes (1). Although numerous submaximal tests have been proposed previously, they usually need special equipment (e.g., treadmill, ergometer) (2), space (at least 20 meters) (3) or skills (e.g., jump rope) (4) which are not always applicable, particularly in young academy clubs encountered with a limited budget. Therefore, to overcome these limitations, developing a submaximal test which does not require special equipment and can be conducted with minimal space is warranted. In this case, step tests are good examples as they require only a bench of a specified height. Stationary runs can be also performed with minimal space and equipment and do not require advanced skills. However, the day-to-day variations in the heart rate responses to such submaximal stationary exercises have not been examined yet.

Aim. The aim of the present study was to compare day-to-day variations in the heart rate responses to a step test and a stationary run in young soccer players.

Methods

Athletes. Twenty young male soccer players (17.4±0.4 y; 70.7±5.0 kg, 177.3±6.9 cm) participated in the study. All players were members of the same team competing in the highest level of Iran soccer league at the U19 age category. All individual players signed an informed consent before commencing the experiment. The study confirmed to the recommendations of the Declaration of Helsinki.

Design. The players repeated four times both the step and the stationary run over 4 consecutive days at the same time of the day. A randomized counterbalanced design was used to diminish any possible order effect. Before these trials, one session was conducted to habituate the players to the study protocol. The study was conducted during the off-season, and players were asked to refrain any type of exercise during the experiment. The submaximal tests were performed indoor with controlled temperature (19-22 °C) and humidity (15-20%). Due to the real submaximal intensity of tests, no warm-up preceded the tests. For all sessions, the players were instructed to sit on a chair for 3 minute before starting the tests. All players were fitted with a Bluetooth heart rate sensor (H7, Polar, Finland) when performing the tests and R-R intervals of the heart rate were recorded on a smart-phone application (Elite HRV) (5). The exported data were later analyzed using Kubios software (6) to calculate heart rate measures including exercise heart rate (HR_{ex}), heart rate recovery (HRR) and 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 an index of post exercise heart rate variability. HR_{ex} was calculated for the last 30 (HR_{ex30s}) and 60 (HR_{ex60s}) seconds of activity for both tests. HRR was also calculated as the number of drops in HR after 60 (HRR_{60s}) and 120 (HRR_{120s}) seconds of recovery. Ln rMSSD was also computed from the post-exercise recovery for one (Ln $rMSSD_{60s}$) and two (Ln $rMSSD_{120s}$) minutes.

Step test. The Young Men's Christian Association protocol was used for the step test implemented in the study (7). A bench (30 cm) and a computerized metronome were used. The players were instructed to step up and down at the cadence determined by metronome frequency (96 beats per minute) of a 24 step cycles per minute. The players were asked to step up and down on the platform at the given rate for a total of 3 minutes and on the completion of the test sit down to have a 2 minutes of passive recovery.

Stationary run. The players were asked to simulate running activity while remaining stationary (on the same place). The players were instructed to lift the knees in front of them and to move their arms similar to running activity. The test duration was 2 minutes and the movement cadence was controlled by a computerized metronome (220 beats per minute). The players were guided to adjust the velocity of stationary run based on the metronome beeps. The players were instructed to sit down for 2 minutes of passive recovery after completing the test. The players performed the test on the same mat for all four trials.

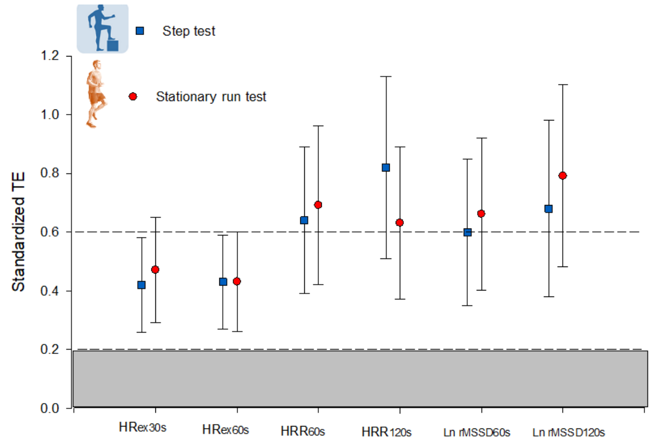

Fig. 1. Standardized typical error of heart rate measures in submaximal tests. Note: Gray area represents trivial typical error (TE), HR_{ex}: exercise heart rate, HRR: recovery heart rate, Ln rMSSD: natural logarithm of the square root of the mean of the sum of the squares of differences between adjacent normal R-R intervals.

Test	Variable	Trial 1 Mean ± SD	Trial 2 Mean ± SD	Trial 3 Mean ± SD	Trial 4 Mean ± SD	All trials Mean ± SD	ICC (90% CL)	CV (noise) (90% CL)	SWC %	Signal %	Signal/ noise ratio
Step test	HR_{ex30s} (beats/min)	138.3 (10.8)	138.4 (9.7)	136.6 (10.7)	136.4 (8.5)	137.5 (10.0)	0.84 (0.73; 0.92)	3.1 (2.6; 3.8)	1.3	4.8	1.5
	HR_{ex60s} (beats/min)	137.5 (11.0)	138.1 (9.7)	136.5 (10.1)	135.8 (8.5)	137.0 (9.9)	0.83 (0.71; 0.91)	3.2 (2.7; 3.9)	1.01	4.8	1.5
	HRR_{60s} (beats)	53.9 (13.3)	59.0 (11.5)	57.2 (17.2)	59.0 (13.4)	57.3 (14.0)	0.61 (0.41; 0.78)	17.1 (14.4; 21.6)	3.8	32.5	1.9
	HRR_{120s} (beats)	73.8 (21.0)	72.5 (19.7)	70.9 (14.4)	66.9 (24.2)	71.2 (19.9)	0.34 (0.12; 0.58)	21.9 (18.5; 27.8)	2.8	32.5	1.4
	Ln $rMSSD_{60s}$	2.7 (0.7)	2.9 (0.7)	2.9 (0.7)	3.0 (0.7)	2.9 (0.7)	0.66 (0.47; 0.81)	16.6 (14.0; 21.1)	4.2	17.6	1.0
	Ln $rMSSD_{120s}$	3.2 (0.7)	3.4 (0.7)	3.4 (0.7)	3.5 (0.7)	3.4 (0.7)	0.56 (0.34; 0.74)	16.1 (13.6; 20.5)	3.2	17.6	1.0
Stationary test	HR_{ex30s} (beats/min)	145.5 (11.3)	144.0 (11.7)	144.3 (11.6)	142.1 (9.2)	144.1 (11.1)	0.88 (0.66; 0.89)	3.7 (3.2; 4.7)	1.01	4.8	1.3
	HR_{ex60s} (beats/min)	143.8 (11.8)	142.8 (11.2)	143.1 (11.5)	141.1 (9.4)	142.8 (11.1)	0.83 (0.72; 0.91)	3.4 (2.9; 4.3)	1.01	4.8	1.4
	HRR_{60s} (beats)	70.4 (17.6)	72.8 (16.3)	73.0 (18.7)	74.0 (20.1)	72.5 (18.1)	0.55 (0.34; 0.74)	19.1 (16.1; 24.3)	1.04	32.5	1.7
	HRR_{120s} (beats)	82.4 (18.1)	89.8 (17.7)	83.1 (14.0)	78.2 (18.0)	83.9 (16.9)	0.72 (0.43; 0.87)	11.4 (9.2; 15.3)	3.4	32.5	2.8
	Ln $rMSSD_{60s}$	3.0 (0.9)	3.2 (0.8)	3.4 (1.2)	3.4 (0.7)	3.2 (0.9)	0.59 (0.38; 0.77)	20.7 (17.3; 26.4)	4.4	17.6	0.8
	Ln $rMSSD_{120s}$	3.6 (0.9)	3.8 (0.8)	3.6 (0.8)	4.0 (0.9)	3.7 (0.8)	0.40 (0.17; 0.63)	20.4 (16.9; 25.8)	3	17.6	0.8

Fig. 2. Characteristics of heart rate measures in submaximal tests. Note: ICC: infraclass coefficient of correlation, CV: coefficient of variation, CL: confidence limits, HR_{ex}: exercise heart rate, HRR: recovery heart rate, Ln rMSSD: natural logarithm of the square root of the mean of the sum of the squares of differences between adjacent normal R-R intervals. SWC: smallest worthwhile change.

Analyses

Data in the table and figure are presented as means with 90% confidence limits (CL) or standard deviation (SD). All data were first log-transformed to reduce bias arising from non-uniformity error. To examine the reliability of both stationary run and step tests over four trials, the intraclass correlation coefficient (ICC) and typical error (TE) of measurement (expressed as coefficient of variation (CV) and standardized, Cohens approach) were computed using a specifically designed spreadsheet (8). ICC results were interpreted based on the classification scale: low (0.26–0.49), moderate (0.50–0.69), high (0.70–0.89) and very high (0.90–1.00) (8). Threshold values for standardized differences were >0.2 (small), >0.6 (moderate), >1.2 (large) and very large (>2) (9). Multiplying the between-subject standard deviation by 0.2 was considered as the smallest worthwhile change (SWC) (10). The usefulness (sensitivity) of heart rate measures was assessed by comparing their signal (training-induced adaptations adopted from the literature (1)) to the noise (TE).

Results

The HR_{ex30s} was the most reliable measure in both submaximal step (ICC: 0.84, CV: 3.1%) and stationary run (ICC: 0.88, CV: 3.7%) tests (Figure 2). HR_{ex} calculated from the last 30 or 60 seconds of activity showed a small TE for both tests while moderate noises were observed in all other measures (Figure 1). However, HRR_{60s} (1.9) and HRR_{120s} (2.8) were observed to be the most sensitive measures of step and stationary run tests, respectively (Figure 2).

Discussion

The main finding of the present study was that new stationary run showed almost similar reliability and usefulness than the step test. This very simple test can be performed in a limited area and can be implemented on a daily basis without space and specific skill requirements. Our results showed that HRex is a less noisy variable compared to all other parasympathetic reactivation measures (i.e., HRR and Ln rMSSD) in both tests. HR_{ex} showed high reliability in both submaximal tests (ICC range: 0.83 to 0.88). These results are in agreement with previous recommendations to use HRex as the most reliable heart rate measure (1). In terms of sensitivity, the TE of all variables was greater than the SWC (Fig. 2), suggesting a low usefulness of the measures (i.e., TE>SWC) (10). However, when considering the TEs in relation to the typical training-induced adaptations of these heart rate measures reported in the literature (1), the signal to noise ratio was greater than 1 for almost all measures, suggestive of a satisfactory level of sensitivity. Following these lines, HRR_{60s} (signal/noise ratio of 1.4; 1.9) and HRR_{120s} (1.4; 2.8) were found to be the most sensitive measures when using the step and stationary run tests, respectively (Fig. 2). The great advantage of the stationary run test is more sport-'specific' than a step test when monitoring team sport athletes. However, the sensitivity of both tests to fatigue and training-induced adaptations need to be investigated in the future studies.

Practical Applications

- A stationary run can be used to monitor athletes' training status when limitations exist in terms of space and equipment.
- It is encouraged to use HRR_{60s} and HRR_{120s} for monitoring the training status of athletes when using step and stationary run tests, respectively

Limitations

- The degree to which knees were lifted during the stationary run was only self-controlled by players - this might have influenced the variation of heart rate measures.

Acknowledgments. We thank soccer head soccer coach Dr. Saeid Jahangiri and all players for their kind cooperation during the experiment.

Dataset

Dataset available on SportPerfSci.com

Twitter: Follow Alireza Rabbani @Alirezarabbani

References

1. Buchheit M. Monitoring training status with HR measures: do all roads lead to Rome? Front Physiol. 2014 Feb;27 (5):1-19.

2. Lamberts RP, Swart J, Noakes TD, Lambert MI. A novel submaximal cycle test to monitor fatigue and predict cycling performance. Br J Sports Med. 2011 Aug;45(10):797-804.

3. Lamberts RP, Lemmink KA, Durandt JJ, Lambert MI. Variation in heart rate during submaximal exercise: implications for monitoring training. J Strength Cond Res. 2004 Aug; 18(3):641-5.

4. Buchheit M, Rabbani A, Beigi HT. Predicting Changes in High-Intensity Intermittent Running Performance with Acute Responses to Short Jump Rope Workouts in Children. J Sports Sci Med. 2014 Sep;13(3):476-82.

5. Perrotta A, Jeklin A, Hives B, Meanwell L, Warburton D. Validity of the Elite HRV Smart Phone Application for Examining Heart Rate Variability in a Field Based Setting. J Strength Cond Res. 2017 Aug;31(8):2296-2302.

6. Tarvainen MP, Niskanen J-P, Lipponen JA, Ranta-Aho PO, Karjalainen PA. Kubios HRV–heart rate variability analysis software. 2014 Aug; 113(1):210-220.

7. Golding L. YMCA fitness testing and assessment manual. ChampaignIllinois: Human Kinetics. 2000.

8. Hopkins W. Analysis of reliability with a spreadsheet. 2012.

9. Hopkins W, Marshall S, Batterham A, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 2009 Jan;41(1):3-13.

10. Hopkins W. How to interpret changes in an athletic performance test. Sportscience. 2004;(8):17.

Copyright: The articles published on Science Performance and Science Reports are distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.