Polar S810 as an Alternative Resource to the Use of the Electrocardiogram in the 4-Second Exercise Test

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Abstract

Background: The 4-second exercise test (T4s) evaluates the cardiac vagal tone during the initial heart rate (HR) transient at sudden dynamic exercise, through the identification of the cardiac vagal index (CVI) obtained from the electrocardiogram (ECG).

Objective: To evaluate the use of the Polar S810 heart rate monitor (HRM) as an alternative resource to the use of the electrocardiogram in the 4-second exercise test.

Methods: In this study, 49 male individuals (25 ± 20 years, 176 ±12 cm, 74 ± 6 kg) underwent the 4-second exercise test. The RR intervals were recorded simultaneously by ECG and HRM. We calculated the mean and the standard deviation of the last RR interval of the pre-exercise period, or of the first RR interval of the exercise period, whichever was longer (RRB), of the shortest RR interval of the exercise period (RRC), and of the CVI obtained by ECG and HRM. We used the Student t-test for dependent samples (p ≤ 0.05) to test the significance of the differences between means. To identify the correlation between the ECG and the HRM, we used the linear regression to calculate the Pearson’s correlation coefficient and the strategy proposed by Bland and Altman.

Results: Linear regression showed r² of 0.9999 for RRB, 0.9997 for RRC, and 0.9996 for CVI. Bland e Altman strategy presented standard deviation of 0.92 ms for RRB, 0.86 ms for RRC, and 0.002 for CVI.

Conclusion: Polar S810 HRM was more efficient in the application of T4s compared to the ECG. (Arq Bras Cardiol 2010;94(5):545-549)

Key words: Muscle tonus; heart rate; exercise; measures; heart.

Introduction

A reduced vagal tone is strongly associated with risk of death by cardiovascular events²⁻⁵. Because of its relationship with cardiac vagal integrity, the behavior of heart rate (HR) has been widely studied in the initial transient of different modalities and conditions associated with exercise. The 4-seconds exercise test (T4s) designed to assess cardiac vagal tone calculates the cardiac vagal index (CVI) from the analysis of the electrocardiographic recording made during the initial transient of HR in sudden dynamic exercise performed under controlled respiratory conditions¹.

In the 1980s, the first heart rate monitors (HRM) to be used during exercise were created. Later, they were validated to monitor the intensity of aerobic activity. In the following years, many studies have confirmed the correlation between HR time series obtained by HRM and the electrocardiogram (ECG) and Holter monitoring during various intensities and forms of exercise⁶⁻¹⁵. With the development of electronic possibilities, some models of HMR as the Polar S810 incorporated, in addition to HR, the ability to record RR intervals. Therefore, Nunan et al¹⁶ found a strong correlation when comparing the recording and issue of RR intervals between the conventional ECG and the Polar S810 HRM at rest, thus proving the capability and applicability of this instrument in the acquisition of data. Finally, relating the validity of those records at various times and maneuvers, Kingsley et al¹⁷ found no significant differences between the measures of Polar S810 HMR and the ECG for all exercise intensities tested.

The T4s protocol includes sudden exercise in cycle ergometer or upper-limb ergometer²⁰ for 4 s, after initial immobility of 4 s. This maneuver causes rapid and large variations in RR intervals. The use of Polar S810 HMR has not yet been studied in a similar situation. Moreover, there is the need to observe whether the amplitude of the agreement interval, occasionally found between the HMR and the ECG, can interfere with the identification of the CVI. Therefore, the objective of this study was to test the operational viability and
use of the Polar S810 heart rate monitor as an alternative to the ECG in the application of the T4s.

Methods

Volunteers

The subjects signed an informed consent about the procedures used in the study. The project was approved by the ethics committee of the institution under No. 171/2008. Subjects with different clinical conditions participated in the study: athletes, beta-blocker users and post-MI patients.

4-second test

Each individual, after a 5-minute rest, underwent 3 consecutive T4s trials, as described in the original protocol 39. The first trial served as a means of familiarization with the procedure, and the best result of the two subsequent trials was chosen as representative of the CVI. The interval between repetitions of the protocol was 1 to 2 minutes, and the subject waited for the HR to return to its pre-maneuver level before repeating the protocol. T4s consisted of a dynamic sudden exercise on a cycle ergometer (Funbec, Brazil) with no resistance (zero charge), from the 4th to the 8th second of maximal inspiratory apnea of 12 s. The individual, after adjusting the saddle and resting for 5 minutes, followed the four consecutive commands, separated by an interval of 4 s, as shown in the diagram in Table 1.

Acquisition of ECG and HMR signals

The RR intervals were recorded simultaneously throughout the test, by the ECG and the HR monitor. We used a digital ECG (Micromed, Wincardio, Brazil) whose signals, recorded at a speed of 25 mm/s, were analyzed by a specific software (PC Ergo Elite version 3.2.1.5). We also used a HMR (Polar S810, Finland) which had an interface (IR interface, Polar Electro OY, Finland) for data transfer to a computer, in which the data were analyzed by a specific software (Polar Precision Performance version 3.01). Of the time series with valid RR intervals, the RRB and RRC intervals, both of the ECG and the HR monitor, were selected to calculate the CVI using statistical treatment the reference time of the commands.

Results

The T4s was applied to 49 males (25 ± 20 years, 176 ± 12 cm, 74 ± 6 kg). The ECG and the HMR recordings were synchronized by time markers (verbal commands). After visual inspection of the records, when the artifacts and characteristic intervals of ventricular premature beats were removed, each observer independently identified the RRB and RRC of each evaluated interval among the valid RR intervals. There was a coincidence of 100% on the location of the identified intervals, and there were no significant differences (p ≤ 0.05) between the means of the measurements made by the ECG and HMR, with a coefficient of correlation r = 0.9999 for the RRB, r = 0.9997 for the RRC, and r = 0.9996 for CVI. The plotting of the differences between means. To identify the correlation between the measurements made by the ECG and HMR, we used linear regression to calculate the coefficient of correlation, and also applied the strategy proposed by Bland and Altman 39, which consists of averaging the individual measurements of ECG (ECG) and HMR (HMR) ([ECG + HMR] / 2) and the plotting of the differences between measurements made by the HMR and these means.

Table 1 - Schedule of application of the 4-second exercise test (T4s)

<table>
<thead>
<tr>
<th>Command</th>
<th>Time (s)</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>Pre-exercise After a quick inhalation through the mouth with maximum inspiration, maintain apnea (until the end of the test), without pedaling, sitting on the bike for 4s.</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>Exercise Maintaining apnea, pedal as fast as possible for 4s (at least 5 rotations of the pedals).</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>Postexercise Stop pedaling abruptly and remain seated on the bike for 4s, maintaining apnea.</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>End of the test Resume normal breathing and finish the test.</td>
</tr>
</tbody>
</table>

Calculation of cardiac vagal index (CVI)

The first step in the calculation of the CVI was the identification of the last RR interval of the pre-exercise period or the first period of exercise (whichever was longer) called RRB, and the shortest RR interval of the exercise period, called RRC. The CVI is obtained by the RRB/RRC ratio. Initially, so as to identify the RRB and RRC the time series of RR intervals obtained by both devices were subjected to visual inspection and removal of artifacts. Then the records underwent an HMR filtering performed automatically by a specific software (Polar Precision Performance version 3.01). Of the time series with valid RR intervals, the RRB and RRC intervals, both of the ECG and the HR monitor, were selected to calculate the CVI using statistical treatment the reference time of the commands.

Discussion

Heart monitors, such as the Polar S810, have been used for measuring HR. In this study, when comparing the results
Table 2 - Values of RRB, RRC and CVI obtained by ECG and HMR

<table>
<thead>
<tr>
<th>RRB (ms)</th>
<th>RRC (ms)</th>
<th>CVI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HMR</td>
<td>ECG</td>
</tr>
<tr>
<td>Mean</td>
<td>869.5</td>
<td>869.3</td>
</tr>
<tr>
<td>SD</td>
<td>154.5</td>
<td>154.2</td>
</tr>
</tbody>
</table>

RRB - last RR interval of the pre-exercise period or the first exercise period, whichever was longer; RRC - shortest RR interval of the exercise period; CVI - cardiac vagal index; ECG - electrocardiogram; HMR - heart rate monitor.

Figure 1 - RRB ECG - last RR interval of the pre-exercise period or the first exercise period (whichever is longer) obtained by ECG; RRB HMR - last RR interval of the pre-exercise period or the first exercise period (whichever was longer) obtained by the heart rate monitor; mean HMR-RRB - mean value measured by ECG and HMR.

Figure 2 - RRC ECG - the shortest RR interval of the exercise period obtained by ECG; RRC HMR - the shortest RR interval of the exercise period obtained by the heart rate monitor; mean HMR-RRC - mean value measured by ECG and HMR.

of T4s obtained by both devices (ECG and HMR), we found a strong correlation, $r^2$ of 0.9999 for the RRB (last RR interval of the pre-exercise period or the first exercise period, whichever was longer), and $r^2$ of 0.9997 for the RRC (shortest RR interval of the exercise period). The high correlation observed in the RRB and RRC resulted in a correlation of 0.9996 in the identification of the CVI, which was obtained by the RRB/RRC ratio. As for the limits of agreement determined by Bland and Altman strategy, we obtained the following results: 0.08 ± 0.92 ms for the RRB, -0.10 ± 0.86 ms for the RRC, and 0.000 ± 0.002 for CVI. There was no significant difference between the measurements ($p > 0.05$).

In this study, the statistical treatment used was similar to others reported here, in order to facilitate the comparison of results. It should be noted that in the present study, we used the RR interval in the initial transient of exercise with sudden onset. Nevertheless, we found values similar to those reported by Kingsley et al and Gamelin et al who studied the validity of HMR in progressive exercise and at rest. The limits of agreement found here were lower than those reported in the studies cited above, perhaps because, in this study we used, in the comparison, only RR intervals used in the identification of the CVI, rather than the complete series (> 5 min), usually used.

There are few data in the literature referring to the efficiency of the Polar S810 HMR to capture the RR intervals of HR for determining the values of the CVI. However, recent studies have demonstrated the effectiveness and applicability of this device in the analysis of the HR variability indexes, in both the time domain and in the frequency domain, thus allowing a reliable, noninvasive, and low cost
assessments of the autonomic balance. Although these are different evaluation methods, both the CVI obtained by the T4s and the indexes adopted for HRV analysis arise from the measurement of RR intervals, which allows us to associate the results found in previous studies. According to the authors’ clinical experience, the application of T4s is a very safe procedure. Although the test has a high arrhythmogenic potential due to rapid changes observed in autonomic activity, no cardiovascular events were observed. Moreover, even if arrhythmias occur, in most cases they are self-limited and of low complexity.

It should be noted that the measurement of the RR intervals monitored by the Polar S810 HMR and transferred to the Polar Precision Performance software is derived from the capture of the electrical pulses generated by the R wave peak of the QRS complex (ventricular depolarization), regardless of whether this was determined by a normal beat originated in the sinus node or by a ventricular premature beat. Therefore, the occurrence of ventricular premature beats during the T4s may limit the interpretation of the RR intervals by the HMR. In our study, this was not a limiting factor, because, upon the occurrence of ventricular premature beats with a too short coupling interval (very early ES), the observer responsible for recording the HMR was able to clearly identify the artifact generated, excluding it from the measurements, which, ultimately, can be confirmed by the high correlation coefficients observed here. However, in ventricular premature beats with a slightly longer coupling interval (close to the baseline measurements of RR), the identification of artifacts by the Polar Precision Performance software becomes significantly more difficult, which may eventually limit the analysis of the measurements used in the method. In this sample of heterogeneous characteristics, with great variability of the CVI, the occurrence of ventricular premature beats became indiscriminated in healthy subjects and in patients with heart disease, and although they were more frequent in the latter, there was no interference in the correct interpretation of the indexes by the HMR observer.

**Conclusion**

We concluded that the Polar S810 HMR can be used as an alternative to the ECG in the application of the T4s. The use of HR monitors increases the possibilities of the application of the T4s. However, it should be emphasized that their use does not replace the ECG in cardiac diagnosis. As the reduction of cardiac vagal tone is associated with an increased risk of death from cardiovascular events, the application of a simple and safe method, such as the T4s, through a more accessible methodology, using the HMR, could permit the identification of a greater number of patients with these characteristics, increasing the benefits derived from this observation. In healthy subjects, it can be applied by health professionals as a routine procedure in the assessment and monitoring of the autonomic changes caused by aerobic training.

**Potential Conflict of Interest**

No potential conflict of interest relevant to this article was reported.

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**Study Association**

This study is not associated with any post-graduation program.

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