

Field Comparison: Zephyr BioHarness™ / Polar HR Monitor



Introduction

The Zephyr BioHarness available from BIOPAC Systems, Inc. monitors Heart Rate (HR) Breathing Rate, Skin Temperature, Posture and Activity. As part of the design and development process, Zephyr is validating each of these parameters against data recorded simultaneously using 'Gold Standard' equipment. This will include comparison against a clinical 12-lead ECG monitoring system.

The Polar Heart Rate monitoring system is well established, and has set the standard by which consumer (i.e. not clinical diagnostic) devices are measured.

The results here have been generated by a human subject wearing both a Zephyr BioHarness and Polar monitoring system simultaneously. A number of exercise protocols and field scenarios have been used. These have been designed to test system performance in the presence of:

- Movement artifacts – electrical noise caused by the movement of the sensor surface with respect to the skin surface
- EMG noise – electrical noise generated by muscle contraction under or adjacent to the sensor surfaces

Conclusions

The Zephyr BioHarness heart rate monitoring performance meets or exceeds the performance of the Polar system throughout the range of tests – activities which maximize the likelihood of noise generated by movement artifacts and EMG simultaneously can result in reduced performance from the Polar system.

The graphs in the Results section clearly show the correspondence between the HR values indicated by both systems.

Note Many of the Polar graphs appear to show 'noisy' HR data. This is a result of plotting the raw R to R data which is provided by the Polar data export software.

This raw data is filtered before it is displayed on the Polar monitor. A plot of the HR actually displayed on the Polar monitor would very closely correlate with the BioHarness data.

Equipment

1. Zephyr BioHarness System

Hardware: Zephyr BioHarness #ZBH000053
Garment: Zephyr Smart Fabric BioHarness Garment #ZSFBH000117
Software: Zephyr BioHarness Application v2.1.0.35

2. Polar Heart Rate monitoring System

Hardware: Polar Wearlink 31 coded transmitter + Polar S810i Heart Rate Monitor
Garment: Electrode strap integrated into Wearlink unit
Software: Polar Precision Performance SW v4.30.040



These systems were worn simultaneously by the test subject, one above the other. It can be argued that there is a 'preferred' position of the two, which is immediately below the pectoral muscles. This places the sensor surfaces as near as possible to the heart itself, with the least amount of muscle tissue underneath. If it was perceived that the performance of one system was affected by not being in the preferred position, the test was repeated with positions reversed.

Test Protocols

A number of activities are used by Zephyr to establish system performance:

1. Internal Laboratory Activities

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|------------------------------|---|
| 1. Static (10 minutes) | The test subject remains stationary during the test, so that no movement artifacts or EMG noise is generated. |
| 2. Arm Lift (5 min) | The subject stands, arms at sides. Both arms are raised simultaneously to vertically upright position and lowered again. This is repeated every ~ 2 seconds. This action is designed to generate both EMG caused by arms lifting, and possible movement artifacts generated at the limit of upward stretch. |
| 3. Thoracic Rotation (5 min) | The subject holds hands together in front of chest (level with devices) with elbows raised, and rotates the torso cyclically to 90° either side of the central position. This is designed to maximize the likelihood of movement artifacts generated by movement of the garment as the torso twists. |
| 4. Chop (5 min) | An exaggerated 'chopping' motion producing a combined lifting and twisting of the torso. |
| 5. 1 kph walk (5 min) | A slow walk on an electric exercise treadmill in the laboratory |
| 6. 5 kph walk (5 min) | As above, but a brisk walk. |
| 7. 10 kph run (5 min) | As above, at a jog/running pace |

2. External Activities

At Zephyr we have an ongoing program of external testing of the BioHarness and other Zephyr products undertaking as many activities as possible. These include running, squash, badminton, ice skating, hang gliding, paragliding, driving, horse riding, mountain biking and sleep monitoring. This program will continue and expand as part of our product development process.

During external tests the Zephyr BioHarness is operated in logging mode, and the data downloaded using the BioHarness application on return to the lab. The Polar monitor is used as a wrist unit, creating its own data files.

Longer comparison tests results shown here include:

1. Multiple running activities within the lab (20 min)
2. 3km run outside (25 min)
3. Ice skating (60 min)

Data Collection

1. Zephyr BioHarness

For laboratory testing the Zephyr BioHarness was set to transmit mode; data is transmitted to a computer running the BioHarness application. Data can be viewed in real-time, and simultaneously recorded by the application. For external tests, the BioHarness was used in logging mode. Data was then uploaded.

2. Polar Heart Rate Monitor

The Polar Wearlink transmitter detects heart QRS cycles and sends radio pulses to the S810i receiver, which logs them to memory. These are then uploaded into the Polar SW application. During all lab tests the receiver was placed on a bench top at waist height next to the subject, no more than 60cm from the transmitter, to reduce the likelihood of radio pulses being lost. For external activities the transmitter was worn as a wrist unit as it was intended.

Recording using both systems was started simultaneously for each activity.

Data Analysis

1. Zephyr BioHarness

The BioHarness application allows for export of data to a csv (comma separated values) file. Heart Rate is explicitly calculated, amongst a range of options available. This is exported into an Excel® spreadsheet. Each value has a corresponding timestamp, measured in milliseconds.

2. Polar Heart Rate Monitor

Data is exported from the Polar SW application into a text file. This consists of a sequence of the R to R intervals in milliseconds. This data is imported into the same spreadsheet as the BioHarness data. No timestamps are recorded. Within the spreadsheet an instantaneous Heart Rate is calculated for each R to R value (60000/value). The R to R intervals are accumulated to create elapsed timestamps for the corresponding calculated HR values.

Both data sets are combined within a single graph within an Excel spreadsheet.

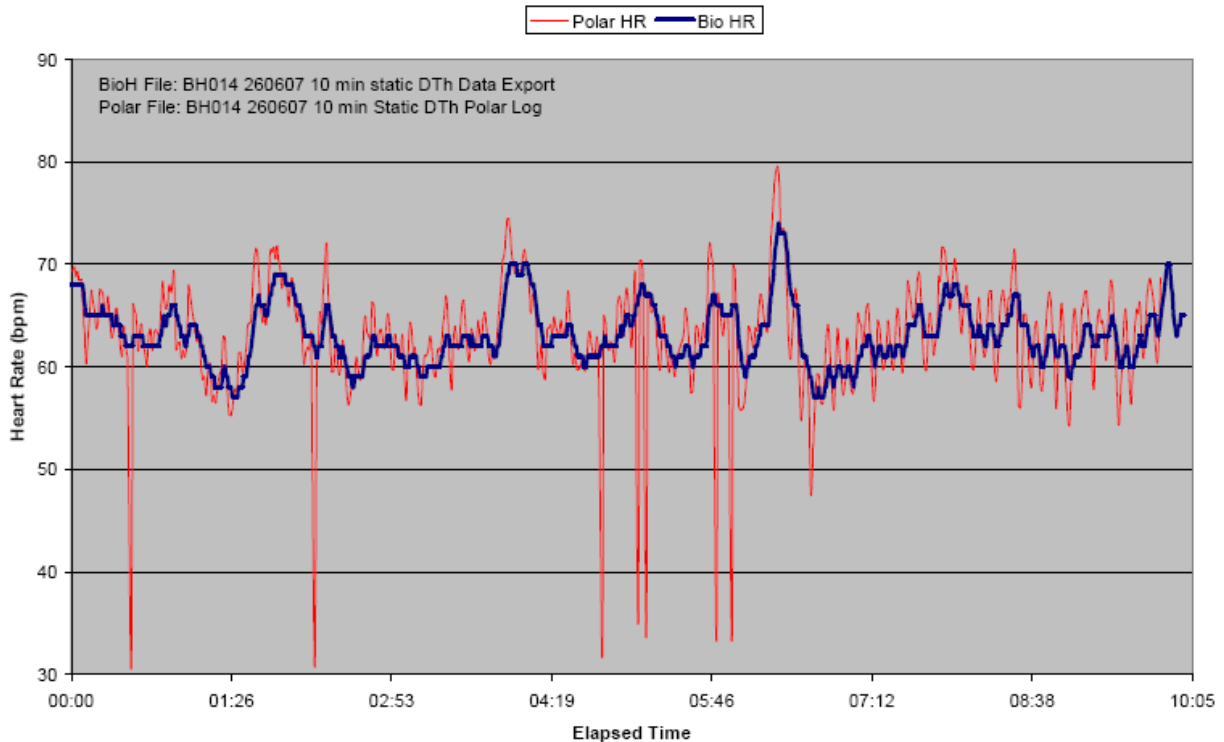
It should be noted that the Polar data sets appear very noisy. This noise is caused by missed radio pulses. These can be caused by a non-detected heartbeat, which may have been obscured by noise at the time of detection, or loss of data during radio transmission. Filtering occurs within the Polar monitor itself which removes this 'noise'. The displayed HR is relatively stable, apart from actual variations in HR caused by the activities. In all laboratory activities, the Heart Rate displayed on both the Polar Monitor and the BioHarness application showed the same value to within 1-2 bpm.

Results

All graphs show two data sets superimposed on the same axes. Timestamps have been adjusted for both sets to show elapsed time in minutes and seconds from the start of the activity.

1. Activity: Static

BH014 BioHarness HR vs Polar HR Static 10 min

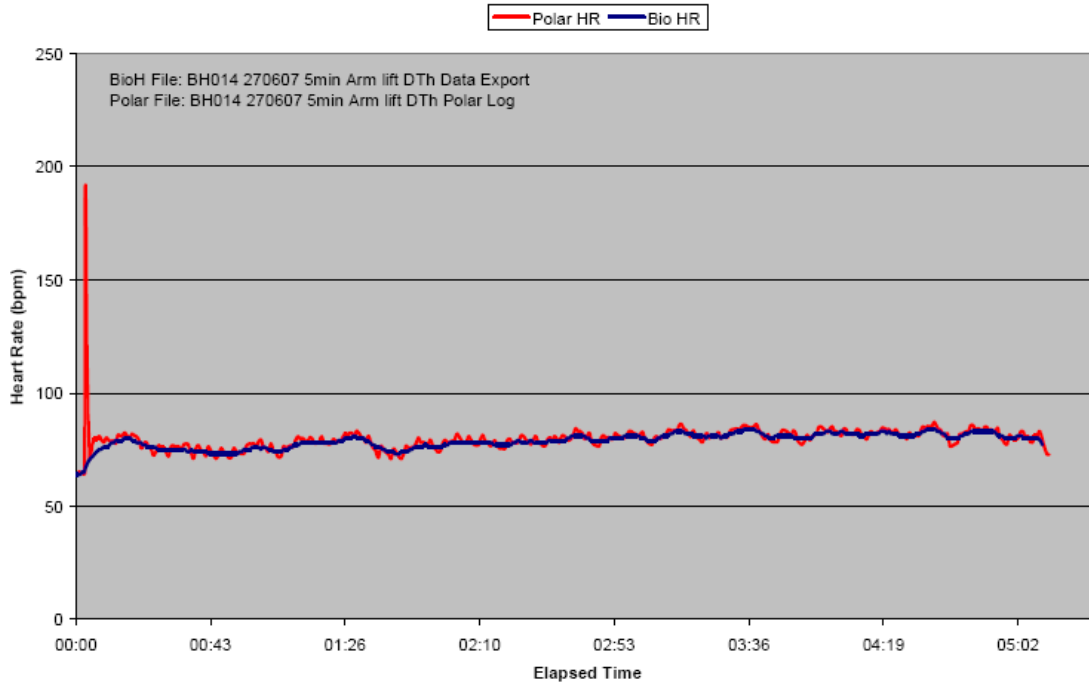


Duration: 10 minutes

Observations: A very close correlation between Polar HR and BioHarness HR was noted. The low levels of noise in the Polar data are not reflected on the actual HR value displayed on the monitor.

2. Activity: Arm Lift

BH014 BioHarness HR vs Polar HR 5min Arm Lift

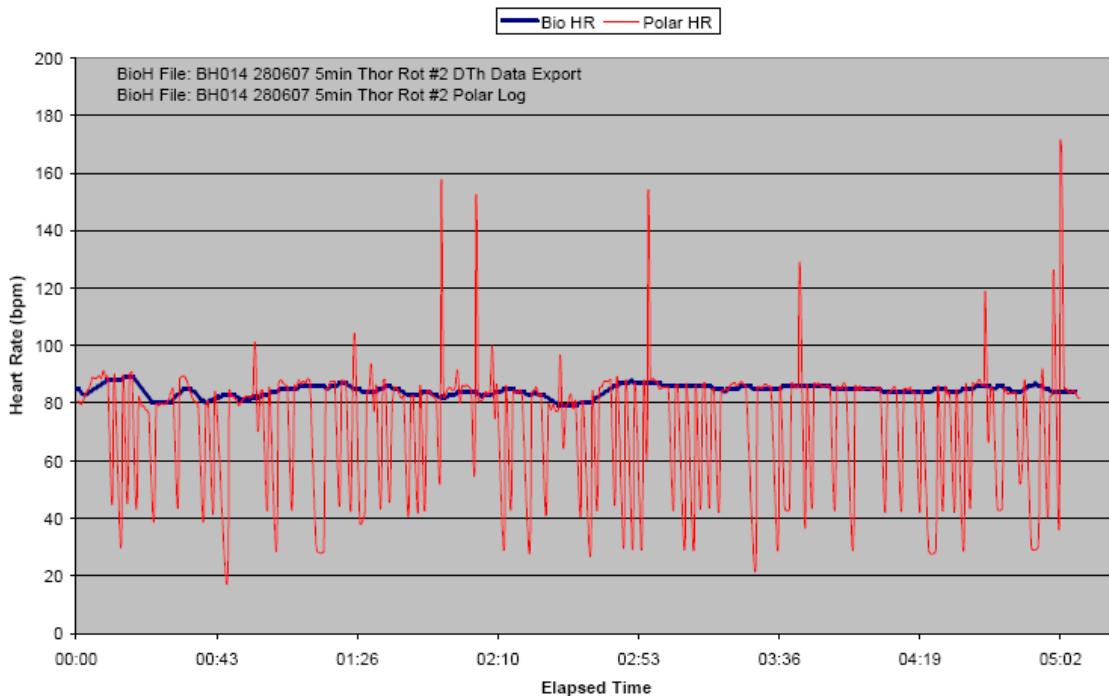


Duration: 5 minutes

Observations: A very close correlation between Polar HR and BioHarness HR. Both recordings show the initial period where detected HR takes a few moments to stabilize.

3. Activity: Thoracic Rotation

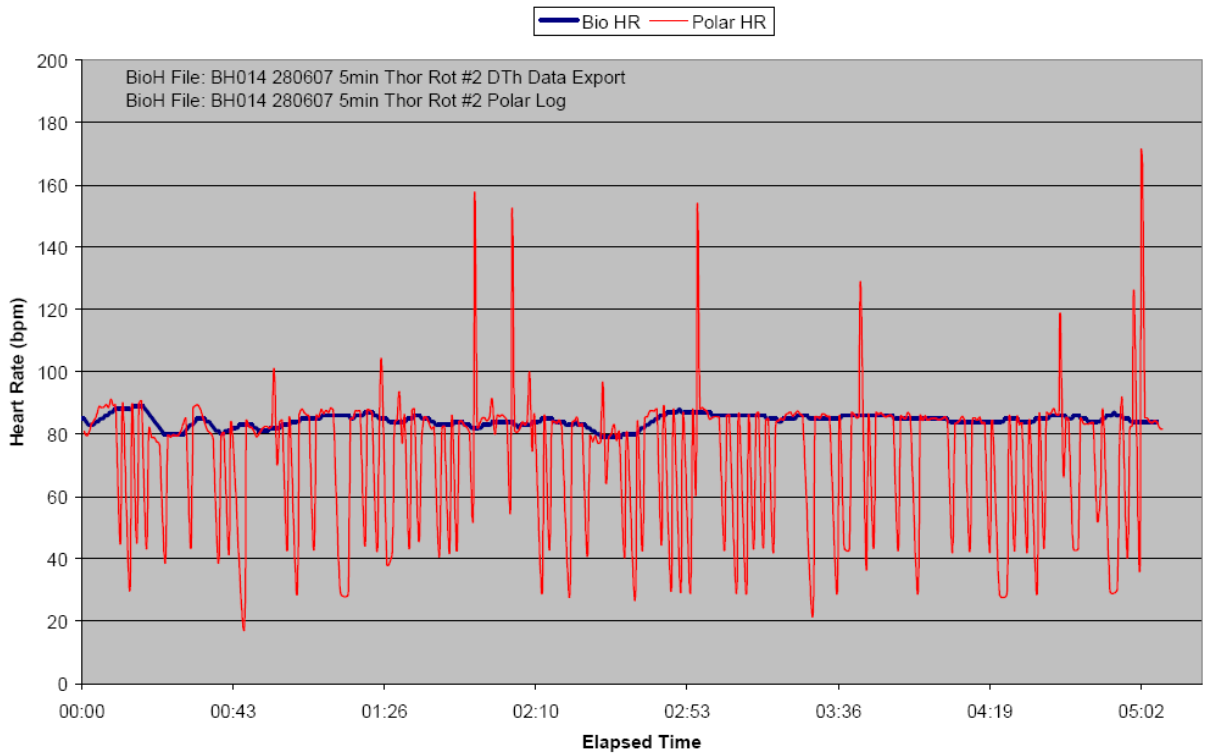
BH014 BioHarness HR vs Polar HR 5min Thoracic Rotation



Duration: 5 minutes

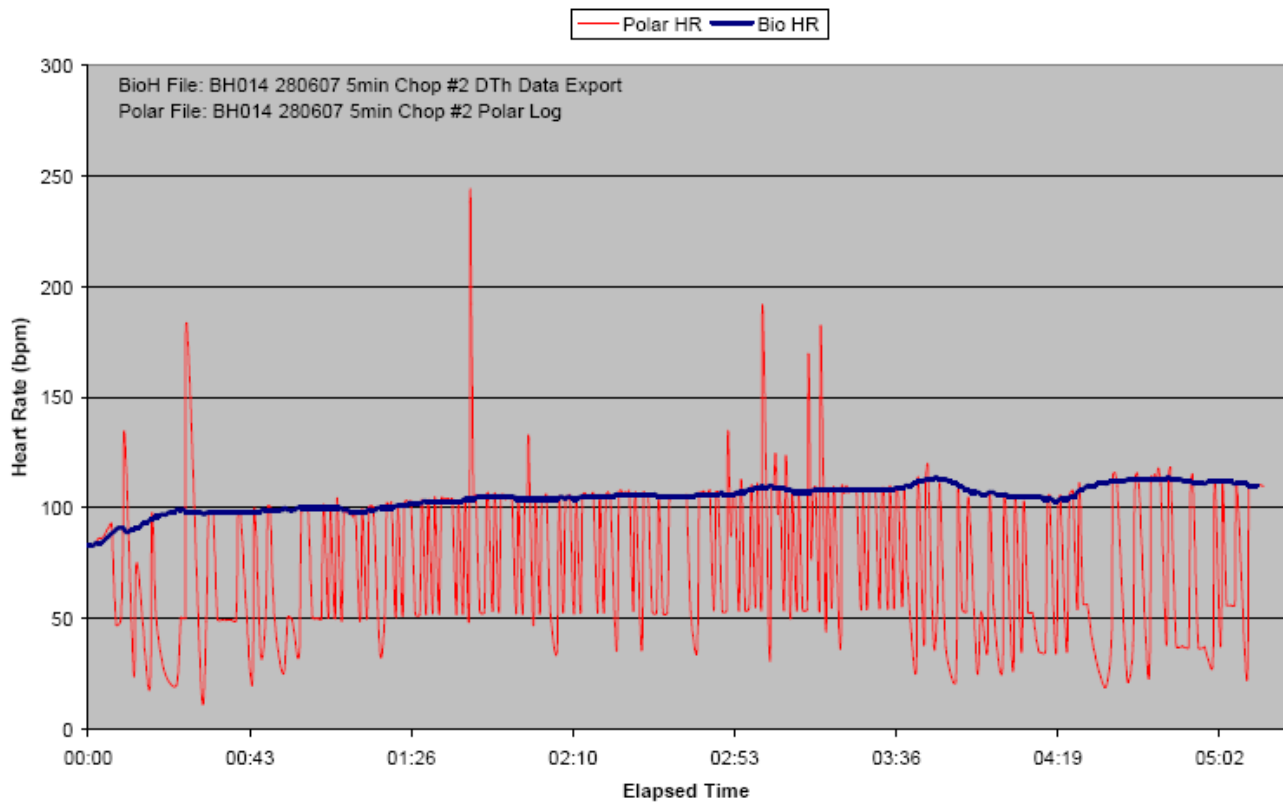
Observations: During the first instance of the test (see next graph), the Polar strap was in the less favored lower position, resulting in greater HR noise levels than had been seen in previous tests. The test was repeated with Polar Monitor above the BioHarness. The actual Polar HR display correlated closely with the BioHarness HR.

BH014 BioHarness HR vs Polar HR Thoracic Rotation 5 min



4. Activity: Chopping Motion

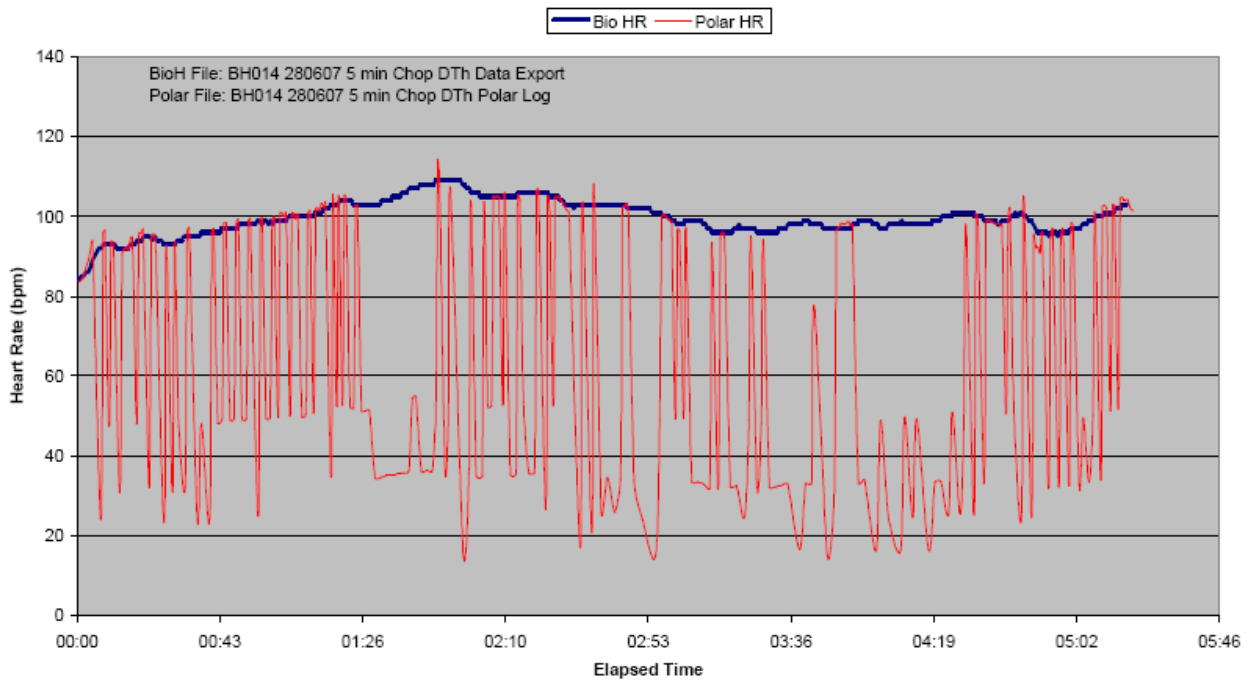
BH014 BioHarness HR vs Polar HR 5min Chop



Duration: 5 minutes.

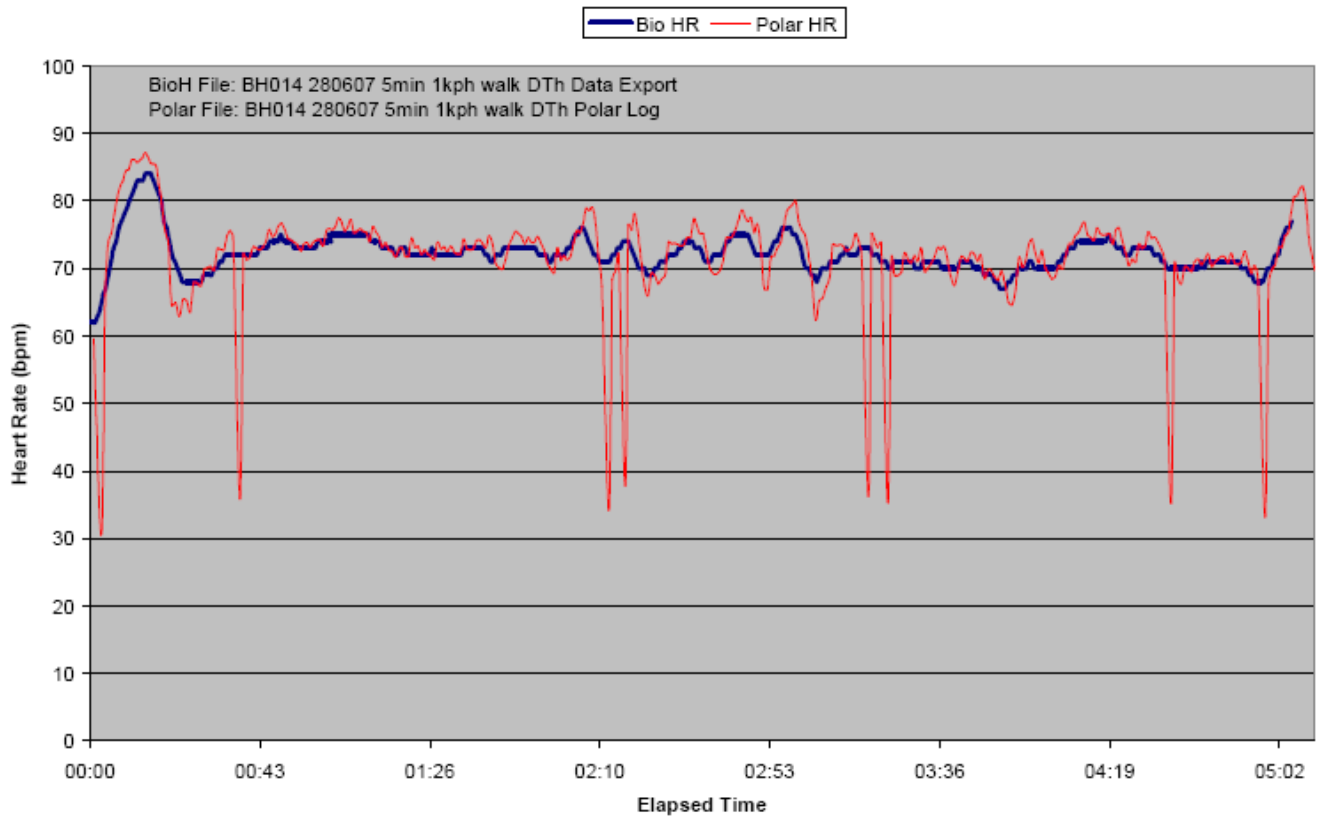
Observations: The above results were obtained with the Polar Wearlink strap in the upper position. This was a repeat of the test with results shown in the [next graph](#), where the Polar heart rate value displayed on the monitor dropped out to less than 50 bpm several times, until the subject stopped the motion, at which point heart rate was detected again by the Polar system.

BH014 BioHarness HR vs Polar HR 5 min Chop



5. Activity: 1 kph walk on treadmill

BH014 BioHarness HR vs Polar HR 5min 1kph walk

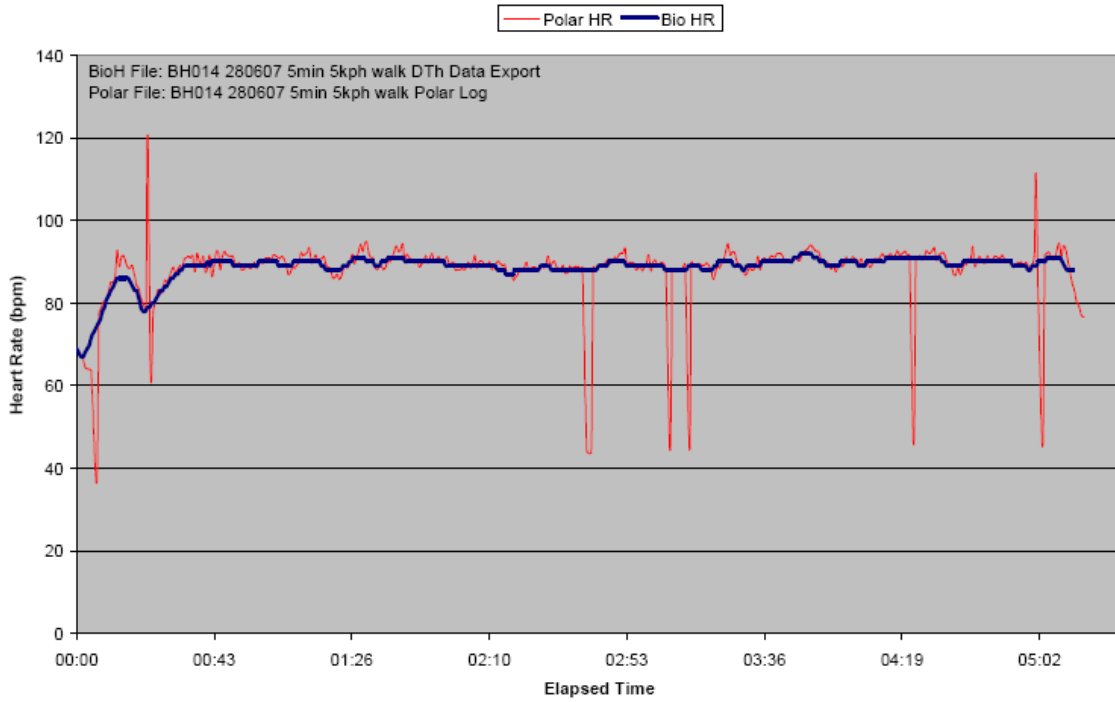


Duration: 5 minutes

Observations: A close correlation between the HR values for both systems.

6. Activity: 5 kph walk on treadmill

BH014 BioHarness HR vs Polar HR 5min 5kph walk

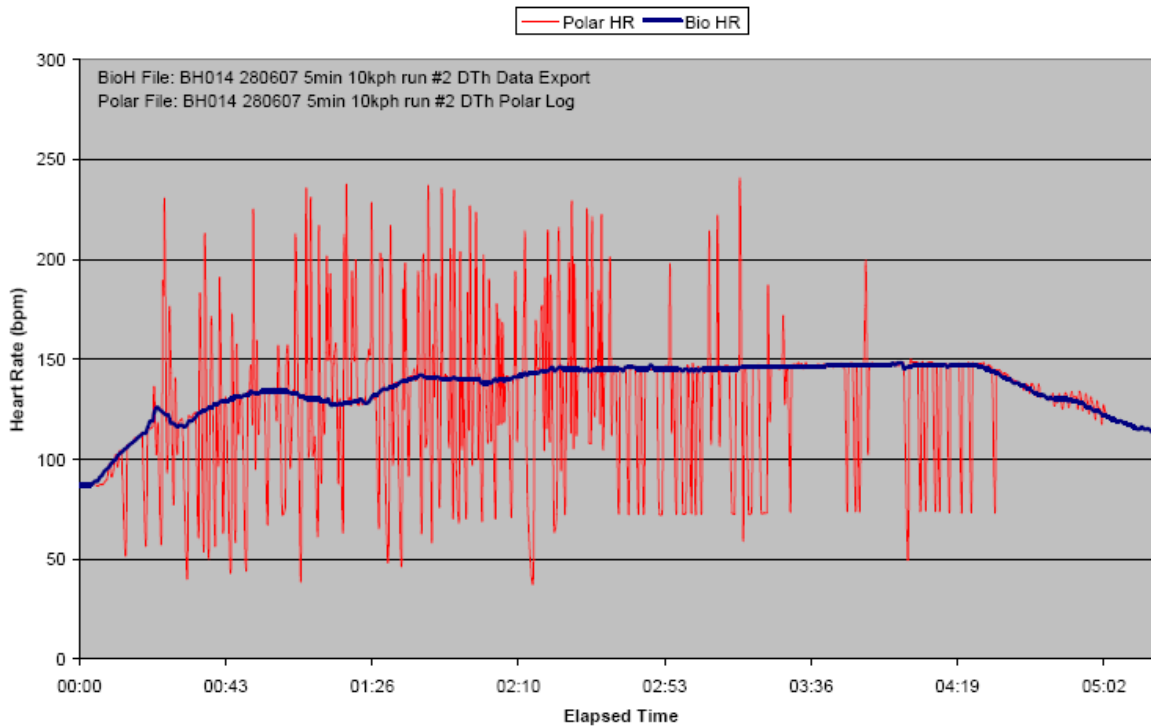


Duration: 5 minutes

Observations: A close correlation between both HR values. The dropouts shown in the Polar HR data here were not seen on the HR displayed on the monitor.

7. Activity: 10 kph run on treadmill

BH014 BioHarness HR vs Polar HR 5min 10kph run

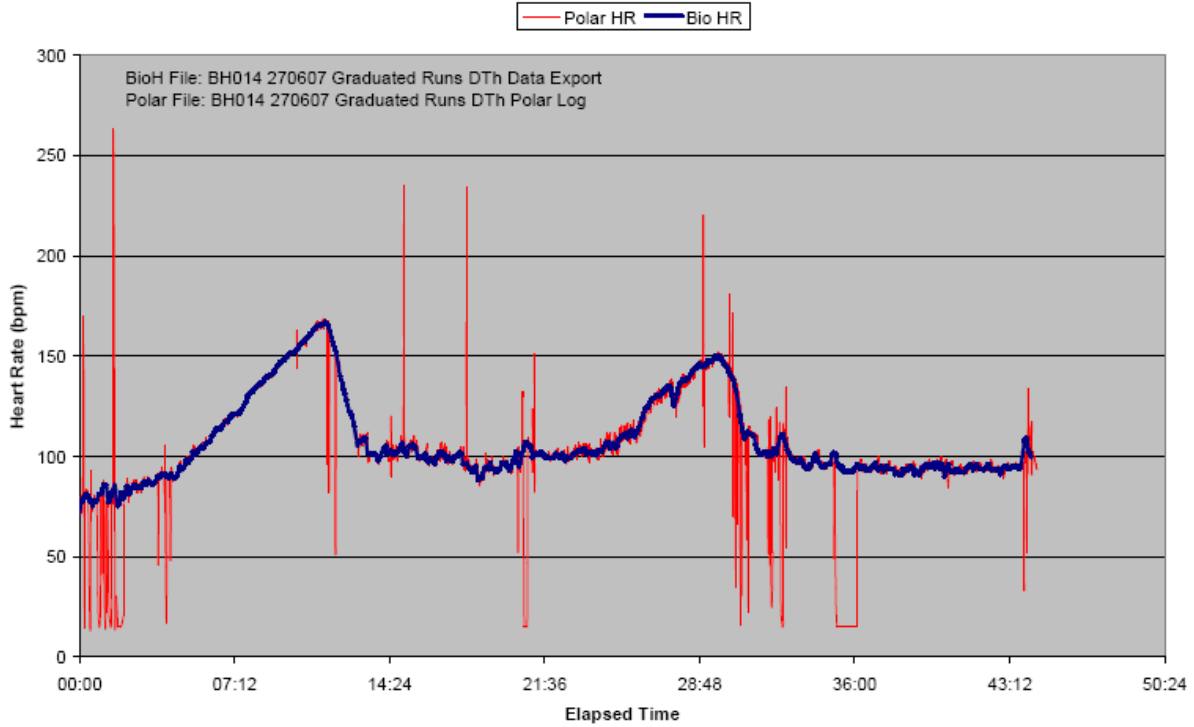


Duration: 5 minutes

Observations: Although the Polar data is very 'noisy' the HR displayed on the Polar monitor correlated closely with the BioHarness HR.

8. Activity: Graduated runs on treadmill

BH014 BioHarness HR vs Polar HR Graduated Runs

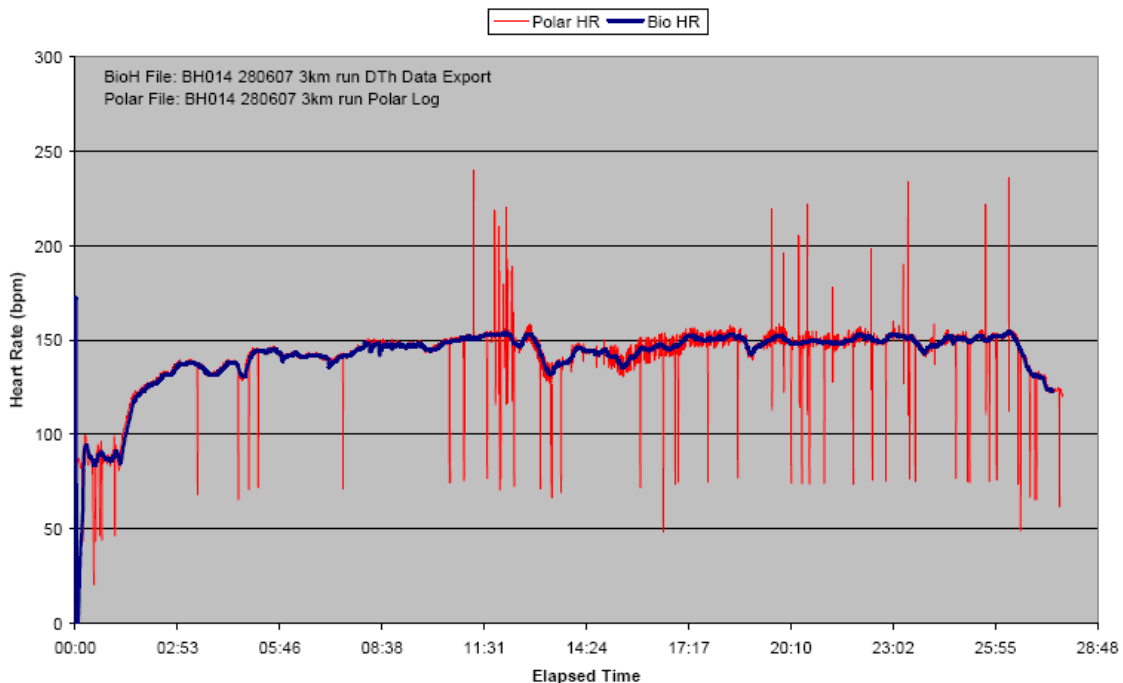


Duration: 45 minutes

Observations: The activity consisted of two sets of running exercises which were being conducted to test Zephyr Shoe Pod technology. A treadmill was used, and running speeds progressively increased from 5 kph to 10 kph, both on an inclined surface (first peak seen), and on a horizontal surface. Both HR monitors were worn continuously throughout the activity session, and displayed HR values correlated closely.

9. Activity: 3 km run

BH014 BioHarness HR vs Polar HR 3km run

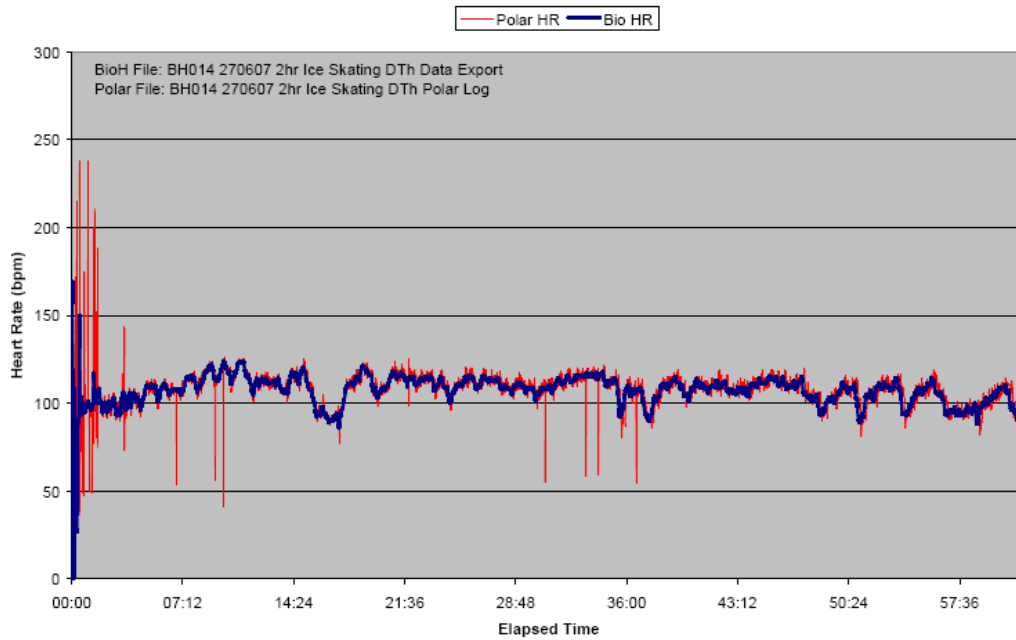


Duration: 25 minutes

Observations: Displayed HR values correlated closely throughout the activity.

10. Activity: Ice Skating

BH014 BioHarness HR vs Polar HR 1 hr Ice Skating



Duration: 1 hour

Observations: After initial stabilization of both HR values, they correlate closely throughout the activity.