Heart Rate (HR)

February 2021

How is LifeQ Heart Rate (HR) validated?

LifeQ compares our Continuous HR solution to the gold standard for HR measurement, an electrocardiograph (ECG). LifeQ uses the Bitium Faros™ 180 ECG device as the reference device of choice.

This device is an ambulatory ECG device that is attached to the participant's chest through a 3-electrode single channel configuration. The HR data obtained from both the LifeQ powered wrist-worn device and ECG reference device is analyzed statistically to assess the accuracy of the LifeQ HR solution.

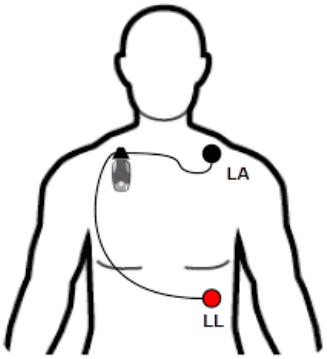


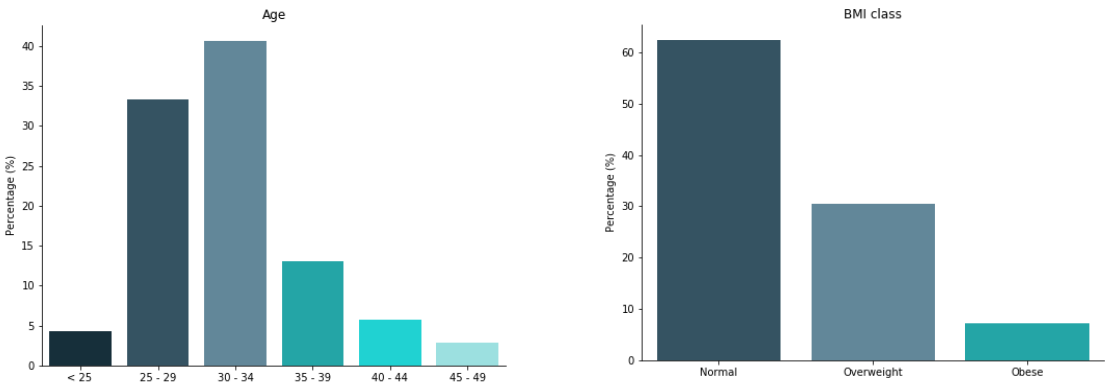
Figure 1: Placement of the Bittium Faros™ device.

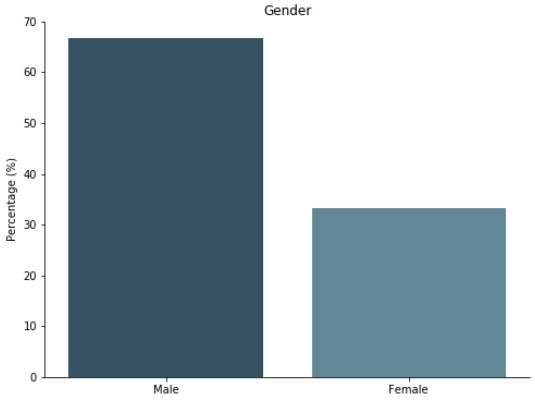
What testing Protocol does LifeQ follow?

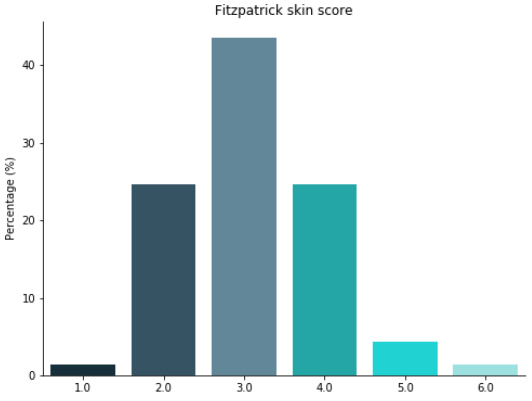
LifeQ uses both controlled (protocol) and uncontrolled (free-living) data to validate our Continuous HR solution.

A wide range of participants are included to ensure we have varying age, ethnicity, gender and levels of physical fitness. A summary of the participants is shown below.

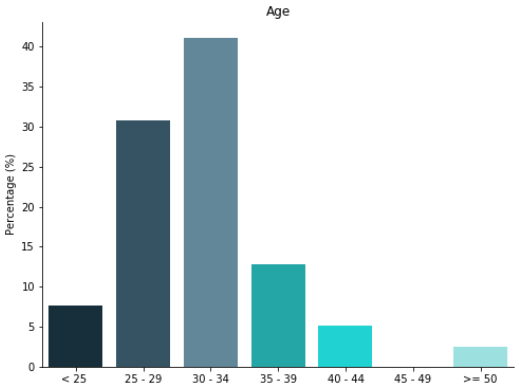
Controlled Setting: LifeQ Exercise Protocol

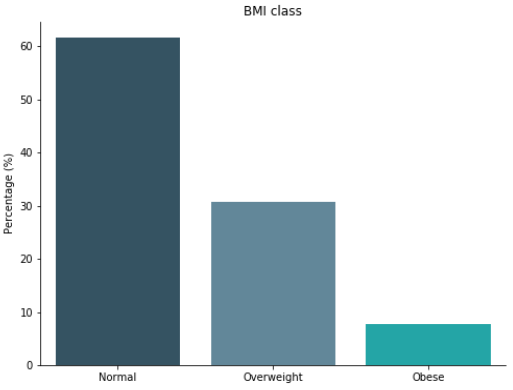


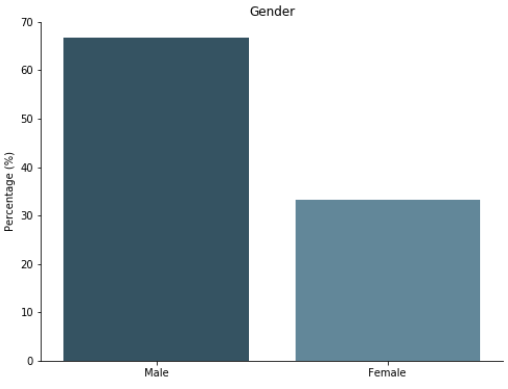


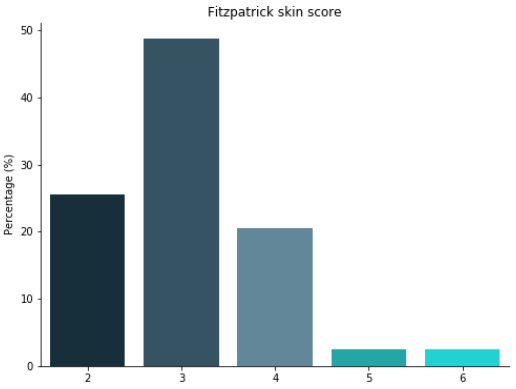


Uncontrolled Setting: 24-hour Continuous Monitoring









Controlled setting: LifeQ Standard Exercise protocol

It is important to control as many variables as possible to ensure a consistent and replicable testing environment. The temperature of the testing room is maintained constant during all testing and participants are instructed to only talk if absolutely necessary, such as to raise concerns about safety or device movement during testing.

The protocol starts with a verbal briefing with emphasis on keeping completely still during the designated rest periods and to not perform any unusual gestures with the hand that is fitted with a wrist-worn device.

The LifeQ Standard Exercise protocol is composed of a variety of exercises, including running, walking, cycling and rowing. The protocol is designed to expose the LifeQ HR solution to various known problem cases where HR is traditionally expected to struggle with good signal quality and therefore HR accuracy. A digital laboratory timer is used to record the start time of each step in the protocol.

LifeQ Exercise Protocol:

1. 2 minutes rest
2. 2 minutes walk (5 km/h)
3. 3 minutes slow run (7 km/h)
4. 2 minutes walk
5. 3 minutes medium run (9 km/h)
6. 2 minutes walk
7. 3 minutes fast run (11 km/h)
8. 2 minutes rest
9. 3 minutes slow cycle (60 rpm)
10. 3 minutes fast cycle (100 rpm)
11. 2 minutes rest
12. 3 minutes rowing
13. 2 minutes rest

Uncontrolled: 24-hour continuous monitoring

This is a 24 hour data collection where the participants do not follow a specific protocol or set of instructions. The participant is fitted with a LifeQ-enabled wrist-worn device and the reference ECG device (Bitium Faros™ 180) for data collection. The participant is instructed to go about their normal routine and to annotate activities such as exercise and sleep times, while wearing the devices constantly.

Accuracy

Device-Based

Table 1: Absolute error during LifeQ exercise protocol for the 10 most recent commercial devices enabled by LifeQ (wide range of designs, sensors and silicon components)

LifeQ Enabled Devices, Beat Per Minute (bpm) Error, Standard Exercise Protocol					
2020-06-09 (DEL v1.67.0_0)			Percentage of data sets falling in accuracy band		
Device	MAE (bpm)	SD Deviation	MAE < 5 bpm	MAE < 10 bpm	MAE < 20 bpm
Device 1	2.43	4.03	89.79%	95.90%	98.92%
Device 2	2.68	4.20	87.30%	95.38%	98.82%
Device 3	2.82	4.71	87.71%	94.43%	98.36%
Device 4	3.37	5.46	82.59%	92.17%	97.35%
Device 5	3.49	5.85	83.67%	92.12%	96.94%
Device 6	4.32	6.13	77.82%	89.13%	96.63%
Device 7	3.52	6.13	82.71%	92.07%	97.11%
Device 8	4.54	7.72	77.76%	88.00%	95.43%
Device 9	3.25	5.51	84.80%	92.71%	97.87%
Device 10	3.46	5.61	83.77%	92.06%	96.72%

Abbreviations: MAE - Mean Absolute Error | SD - Standard Deviation

Activity-Based

Table 3: Accuracy across all datasets for different types of activities

Activity	# Datasets	MAE	SD
24-hour (Full)	144	3.62	7.17
24-hour (No Motion)[1]	144	1.18	1.44
Exercise Protocol (Full)	584	3.53	5.77
Exercise Protocol (Walk)	1752	4.00	3.66
Exercise Protocol (Slow Run)	584	4.68	4.44
Exercise Protocol (Med Run)	584	3.80	4.13
Exercise Protocol (Fast Run)	584	3.76	3.98
Exercise Protocol (Cycle)	584	1.25	1.82
Exercise Protocol (Row)	584	6.19	5.94

Abbreviations: MAE - Mean Absolute Error | SD - Standard Deviation | coefficient | MAE% Error - Mean Absolute percentage error

[1] No motion heart rate is when the LifeQ algorithm uses RR (beat-to-beat) algorithm to calculate heart rate.

Table 4: Distribution of error across the data sets for different types of activities

Activity	Error <5%	Error <10%	Error <20%
24-hour (Full)	75.99	88.43	96.13
24-hour (No Motion)[1]	95.39	98.75	99.86
Exercise Protocol (Full)	84.35	92.67	97.70
Exercise Protocol (Walk)	78.72	90.75	97.17
Exercise Protocol (Slow Run)	80.25	90.03	96.11
Exercise Protocol (Med Run)	83.46	91.60	97.87
Exercise Protocol (Fast Run)	85.66	92.84	97.80
Exercise Protocol (Cycle)	97.19	99.00	99.75
Exercise Protocol (Row)	72.90	84.26	94.41

[1] No motion heart rate is when the LifeQ algorithm uses the LifeQ BBI algorithm to calculate heart rate.

Constraints in measuring HR accurately

Measuring HR from a wrist-based device is complex and the technology has limitations owing to the nature of the quality and coverage of the available PPG signal. LifeQ's solutions are built to overcome and mitigate as many as possible of these issues. However it is important to be aware that low temperature, dark skin color, high motion, hand/ wrist pressure, mechanical fit of the device and user blood perfusion levels can all negatively impact the quality and coverage of the PPG signal and as a result the solution itself.