

## Firstbeat analysis server for research use

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## Guidelines for research with Firstbeat Lifestyle Assessment

### GENERAL

- The method is based on physiological modelling of the body based on heart rate variability (HRV) and 3D acceleration data. HRV is a non-invasive tool for exploring autonomic modulation of the heart, including parasympathetic (vagal) and sympathetic effects.
- The software requires some background information about the users [gender, date of birth (age), height, weight, physical activity class]. Based on the background variables, the software seeks from the data and/ or estimates a physiological range for each user (e.g. VO2max, HRmax, HRmin). If this information has been measured in a laboratory, it can be added to the system and it improves the accuracy of the measured parameters.
- It is recommended to have a long enough measurement period, including daytime and sleep time data, to allow full calibration of the system for the individual. Typically, it is better to have data from more than one day for each person. The current service model by Firstbeat is based on 3-day measurements. Note! If only standard HR and HRV parameters are used in research, the individual calibration period is not necessary.
- It is extremely important that there is data only from one person at a time in the device. Therefore, the same device should not be worn consecutively by different people without uploading the data and emptying the device between the measurements as this mixes up the physiological range evaluation for a particular person. **The data should always be uploaded, and the device emptied, and the battery charged before attaching the device on the next person.**
- If comparable results between different time periods (e.g. pre, post) are to be acquired, it is important to use the **same background parameter values** in each measurement.
- Research use of the Lifestyle Assessment allows the data to be exported into three separate information sheets, including raw data, HRV data (RMSSD 1 min and 5 min), and overall results as scalars (averages of the whole measurement) and vectors (second-by-second data).
- It is important to have technical skills for analyzing large data sets. For example, Matlab software can be used to extract the desired information from the data sheets to be input for example into the SPSS statistical tool.

## ILLNESSES

- Fever is the most common example of an acute illness that affects strongly on physiology and HRV metrics, seen as reduced recovery. Thus, if comparable results are desired between measurements it is not recommended to conduct a measurement during fever. Strong infections can also significantly weaken recovery.
- The measurement is not recommended for people who have a cardiac pacemaker, have had a heart transplant or suffer from a serious heart condition, chronic atrial fibrillation or flutter or uncontrolled thyroid dysfunction. In these cases, the results can be misleading, or their reliability can be weak.
- If the client has a lot of different illnesses and medications, it can be difficult to draw appropriate conclusions from the result. Thus, the researcher should consider, case-by-case, whether it is sensible to conduct the measurement.

## MEDICATIONS

Medications that increase or decrease the heart rate can weaken the reliability of the analysis result by changing the way the nervous system reacts and giving a somewhat misleading view of the body's stress level, recovery or energy expenditure.

Particularly the following medications can cause challenges in interpreting the result accurately:

- Beta blockers
- Tricyclic or other activating antidepressants
- Long-acting sleep medications
- Pain medications that affect the central nervous system
- Strong medications for psychosis, arrhythmia and neurologic disorders

Beta blockers decrease the heart rate level at rest and during exertion. If the client has listed a beta blocker under Medications, in most cases, it is recommended to reduce the maximum heart rate by 15-20 beats (under personal information), to make the analysis more reflective of the person's situation.

## ALCOHOL AND STIMULANTS

- Alcohol has a big effect on the autonomic nervous system and HRV. There is a dose-response relationship between dosage of alcohol and reduced recovery. As little as two units of alcohol in the evening can elevate the heart rate level for several hours. In order to measure the resting heart rate reliably, it is recommended to have at least one night in the assessment period without any alcohol. In a study where reliable and comparable results between days are desired, it is better to instruct the research subjects to avoid drinking any alcohol during the measurement.
- Other drugs and stimulants, such as cigarettes, chewing tobacco and energy drinks can also increase the heart rate level and cause challenges in determining an accurate resting heart rate. This can weaken reliability, especially when it comes to recovery.

### MISSING HEART RATE DATA

- Missing heart rate (%) consists, for example, of measurement breaks (e.g. shower), weak electrode contact with the skin (e.g. very damp skin, poor attachment, or old / dried up electrodes) or some kind of irregular heart rhythm
- A high amount of missing heart rate does not allow the system to get reliable R-R data, which weakens the accuracy of physiological analytics.
- If there is more than 15% / day of missing heart rate data and it occurs systematically throughout the day (instead of 1 long measurement break), the reliability of the result is weakened for that day. If the share of missing data is over 15% on two out of three days, a new measurement is recommended. It's best to make the new measurement with a different device to rule out possible device failure.

### PHYSICAL ACTIVITY

- Very strenuous exercise will have a significant impact on the body's stress level (physiological activation) for some time after exercise. The harder the exercise session is for the individual, the bigger the impact. Especially late-evening exercise can cause a significant delay before recovery starts during sleep. For the best possible comparison between different days in a research project, or to show the effects of a specific intervention, it is better to avoid very strenuous exercise.

## Firstbeat research tool for 24h HRV measurements

Firstbeat provides complete tools for 24h monitoring and analysis of heart rate variability (HRV) and acceleration in real-life measurements. Our methods are used in exercise and training research, behavioral sciences, wellness coaching and health promotion, ergonomics and work studies.

- HRV and autonomic nervous system balance
- Within-day stress and recovery profiles
- Recovery analysis during sleep
- Exercise intensity and physical activity
- Fitness level (VO2max) evaluation
- Energy expenditure
- Workload assessments

### BODYGUARD 2 HRV RECORDER



Bodyguard 2 is a lightweight device for measuring 24h HRV (RR-intervals) and 3-axis acceleration. The device is designed for robust and reliable real-life (ambulatory) measurements. The device is attached to a person using two standard electrodes and data is loaded to a PC through USB.



## FIRSTBEAT LIFESTYLE ASSESSMENT

Cloud service is available in English, Finnish, Swedish and German

### Reports (pdf)

- Individual Reports: Lifestyle assessment, Lifestyle assessment summary, Training effect, Physical workload, Lifestyle assessment follow-up.
- Anonymous group reporting tools: Summary of the Firstbeat Assessment, Physical Workload Group Report, Pre-Questionnaire Group Summary.
- Specialist reports on HRV based stress classification
- Graphs include for example heart rate, stress, recovery and physical activity periods and intensity, HRV, energy expenditure and EPOC.
- Possibility to customize the reports' visual image.
- Reports are available in English, German, French, Swedish, Hungarian, Norwegian, Portuguese and Finnish.
- Example reports can be found at <https://www.firstbeat.com/en/%20wellness-services/wellness-professionals/technical/>

### Automated heart rate variability (HRV) analysis

- Automated correction of measurement errors in beat-by-beat heart rate (required for HRV analysis)
- HRV-based stress and recovery state classification for 24h data, stress and recovery summary indexes (autonomic balance)
- Physical activity measures (indirect): VO<sub>2</sub>, %VO<sub>2</sub>max, EPOC, training effect, energy expenditure
- Detection of HRV irregularities
- HRV measures: VLF, LF, HF, LF/HF, RMSSD.
- Analysis has been developed based on physiological autonomic nervous system (ANS) research.

### Communication tools and diaries

- Tools supporting personal lifestyle goal setting
- Web-based electronic diary and personal information request tools. Support for email communications.
- Customizable email forms for automated messaging with the customers

### Data export for researches

- Option to export second-by-second data or summary data for all HR, HRV and physical activity measures
- Data export in .csv files for single measurements and for multimeasurements
- Profile and data exports/imports in FBE-file format

### System requirements and compatible hardware

- Windows or Mac user interface. Screen resolution 1024X768, 16-bit colour package
- Direct upload from Firstbeat Bodyguard 2; Firstbeat Bodyguard via Firstbeat Plugin

### Administrative tools and security

- Professional users' account management
- System statistics and access logs
- Customization tools and system options
- SSL secured communications and password access security
- Built-in user instructions and guidance (Learning Center)

For more information and local distributors, please visit [firstbeat.com](http://firstbeat.com).

## Data files available from Firstbeat analysis server for research use

### 1) RR-interval Data Export

Firstbeat analysis server contains a data export feature that allows the essential information calculated from heartbeat data to be stored into a .csv file. This file format is compatible with common data analysis programs, e.g. MS Excel and SPSS. Once enabled for the account, the data export feature is available in the main view of the analysis server. To upload the raw data in offline mode, please see the instructions [here](#).

#### CSV Files

Data export provides three separate files. The first one (\_IBI suffix in the file name) contains the analysis version, measurement start time, original and corrected RR data and artifact data that counterparts with corrected RR data and tells if the RR-interval is modified with artifact correction. The second file (\_MiscVectors suffix in the file name) contains the analysis version and an RMSSD vector in 5- and 1-minute sampling frequency. The third file is the main export file containing the most essential analysis results.

The table below describes the main export file (.csv format) produced by the Data export. One file includes data from a single analyzed session. The file consists of PERSON PROFILE info, SCALAR VARIABLES and VECTORS. PERSON PROFILE includes the personal background values used in the analysis. SCALAR VARIABLES are average values calculated for the session and VECTORS show the values from each respective moment of the session. The sampling frequency of the vectors is one second, meaning that each data point corresponds to one second in time, i.e. a vector that is 120 points long corresponds to two minutes in time.

PERSON PROFILE		
Identifier	Unit	Explanation
Person name		Name
Date of birth	dd.mm.yyyy	Date of birth
Gender		Gender
Height	Cm	Height
Weight	Kg	Weight
Activity Class	(0 -> 10)	Activity class 0-7 according to Jackson et al. (1990), 7.5, 8, 8.5, 9, 9.5 and 10 according to Firstbeat
Heart beat max	times/min	Maxium heart rate
Heat beat min	times/min	Resting (minimum) heart rate
MET max	MET	Maximal performance METs (MET max = $VO_{2max}$ (ml/kg/min) / 3.5 ml/kg/min), if provided
SCALAR VARIABLES		
Identifier	Unit	Explanation
SessionStartDate	dd.mm.yyyy	Session start date
SessionStartTime	hh:min:sec	Session start time
SessionTotalTime	Min	Session total time
DetectedArtifactPercentage	%	Grade of detected and corrected artifacts in RR Vector.
RelaxationTime	Min	Total time of relaxation
StressTime	Min	Total time of stress
TimeBelow20pMETMax	Min	Total time in minutes of periods where intensity was less than 20% of METmax.
Time20pTo30pMETMax	Min	Total time in minutes of periods where intensity was between 20% and 30% of METmax.
TimeOver30pMETMax	Min	Total time in minutes of periods where intensity was over 30% of METmax.
Time4MinPeriods30pTo40pMETMax	Min	Total time in minutes of over 4-minute periods where intensity was between 30% and 40% of METmax.
Time4MinPeriodsOver40pMETMax	Min	Total time in minutes of over 4-minute periods where intensity was over 40% of METmax.
AverageHR	times/min	Session average heart rate
AverageRespR	times/min	Session average respiration rate
AverageVentilation	l/min	Session average ventilation
AverageVO2	ml/kg/min	Session average oxygen consumption
AveragepMETmax	%	Session average relative oxygen consumption
MaxHR	times/min	Session highest 10-second average heart rate
MaxRespR	times/min	Session peak respiration rate

MaxVentilation	l/min	Session peak ventilation
MaxVO2	ml/kg/min	Session peak oxygen consumption
MaxpMETmax	%	Session peak relative oxygen consumption
MinHR	times/min	Session lowest 10-second average heart rate
EETotal	Kcal	Session total energy expenditure
EECH	Kcal	Session total energy expenditure from carbohydrates
EEFat	Kcal	Session total energy expenditure from fat
EEPredictRest	Kcal	An estimate of energy expenditure for 24 hours based on the measurement. For the unmeasured period it is assumed that energy expenditure is at resting level.
EEBelow20pMETMax	Kcal	Total energy expenditure in periods where intensity was less than 20% of METmax.
EE20pTo30pMETMax	Kcal	Total energy expenditure in periods where intensity was between 20% and 30% of METmax.
EEOver30pMETMax	Kcal	Total energy expenditure in periods where intensity was over 30% of METmax.
TrainingEffect	(1.0 -> 5.0)	Training Effect revealing the effect of the exercise session on performance level
EPOCPeak	ml/kg	Session peak EPOC value
HealthIndex	(0 -> 100)	Health index revealing whether the physical activity in the measurement had health-enhancing effects
AbsoluteStressIndex	Index	Absolute index of stress as the average absolute stress level of the session during periods when stress state is detected
AbsoluteRelaxationIndex	Index	Absolute index of relaxation as the average absolute relaxation level of the session during periods when relaxation state is detected
RelaxationPercentage	%	Proportion of relaxation from the session total time
StressPercentage	%	Proportion of stress from the session total time
StressBalance	(-1.00 -> 1.00)	Index revealing the balance between stress and relaxation. Negative values indicate that the balance is towards relaxation
BeatByBeatRMSSD	Ms	Heart rate variability variable RMSSD (Root Mean Square of Successive Differences in RR intervals) describing the variation in consecutive rr-intervals.

BeatByBeatSD	Ms	Heart rate variability variable: standard deviation of successive heartbeat intervals of the whole session
HFAverage	ms <sup>2</sup>	Mean of the high frequency (0.15-0.4 HZ) heart rate variability power during the session
LFAverage	ms <sup>2</sup>	Mean of the low frequency (0.04-0.15 HZ) heart rate variability power during the session
HF2Average	ms <sup>2</sup>	Mean of the high frequency (0.15-1.0 HZ) heart rate variability power during the session
LFHFRatio	Ratio	Mean ratio between the low frequency (0.04-0.15 HZ) and high frequency (0.15-0.4 HZ) heart rate variability power (LF/HF) during the session
LFHF2Ratio	Ratio	Mean ratio between the low frequency (0.04-0.15 HZ) high frequency (0.15-1.0 HZ) heart rate variability power (LF/HF2) during the session
<b>VECTORS</b>		
Identifier	Unit	Explanation
CumulativeSecondVector	hh:min:sec	Cumulative time starting from the beginning of the session
RealTimeVector	hh:min:sec	Real time
StateVector	(1 -> 10)	State vector indicating which Firstbeat identified state is currently "on" at each respective moment. State indexes: 1) hard physical exercise >85%VO <sub>2max</sub> , 2) vigorous physical activity 60-85%VO <sub>2max</sub> , 3) moderate physical activity 40-60%VO <sub>2max</sub> , 4) light physical activity, 6) relaxation, 7) recovery from physical exercise, 9) stress, 10) unrecognized state.
ArtifactCorrectedHRVector	beats/min	Artefact corrected heart rate vector
METMaxPercentageVector	%	Proportional intensity vector: oxygen consumption vector scaled according to maximal oxygen consumption
VO2Vector	ml/kg/min	Oxygen consumption vector
EPOCVector	ml/kg	EPOC vector
RespRVector	breaths/min	Respiration rate vector
VentilationVector	liters/min	Ventilation vector
EEVector	kcal/min	Total Energy expenditure vector
EepFatVector	kcal/min	Energy expenditure from fats vector

ResourceVector	Index	Resources vector revealing the accumulation or reduction of body resources during the session
AbsoluteStressVector	Index	Absolute vector of stress, revealing the momentary absolute level of stress during the session
AbsoluteRelaxationVector	Index	Absolute vector of relaxation, revealing the momentary absolute level of relaxation during the session
ScaledStressVector	(0.00 -> 1.00)	Relative vector of stress, revealing the momentary proportional level of relaxation proportioned by the maximal relaxation value during the session
ScaledRelaxationVector	(0.00 -> 1.00)	Relative vector of relaxation, revealing the momentary proportional level of relaxation proportioned by the maximal relaxation value during the session
VLFFvector	ms <sup>2</sup>	Vector of very low frequency (0.03-0.04 Hz) heart rate variability power, determining the momentary level of heart rate variability at this spectral band during the session
LFVector	ms <sup>2</sup>	Vector of low frequency (0.04-0.15 Hz) heart rate variability, determining the momentary level of heart rate variability at this spectral band during the session
HFVector	ms <sup>2</sup>	Vector of high frequency (0.15-0.4 Hz) heart rate variability power, determining the momentary level of heart rate variability at this spectral band during the session
HF2Vector	ms <sup>2</sup>	Vector of very low frequency (0.15-1.0 Hz) heart rate variability power, determining the momentary level of heart rate variability at this spectral band during the session
RSAAmplitudeVector	Ms	Vector of RSA (respiratory sinus arrhythmia) amplitude, which is determined as the mean heart rate variability power at the heartbeat derived respiration frequency (+0.01- -0.01). This reveals the effect of respiration on heart rate variability power.

## 2) Acceleration data export

Firstbeat Bodyguard measures 3D acceleration. You can find the acceleration data (.csv) on your computer. The path is (for example) C:\Firstbeat Files\Uploader Plugin\Eddie Example\Loaded RR files.

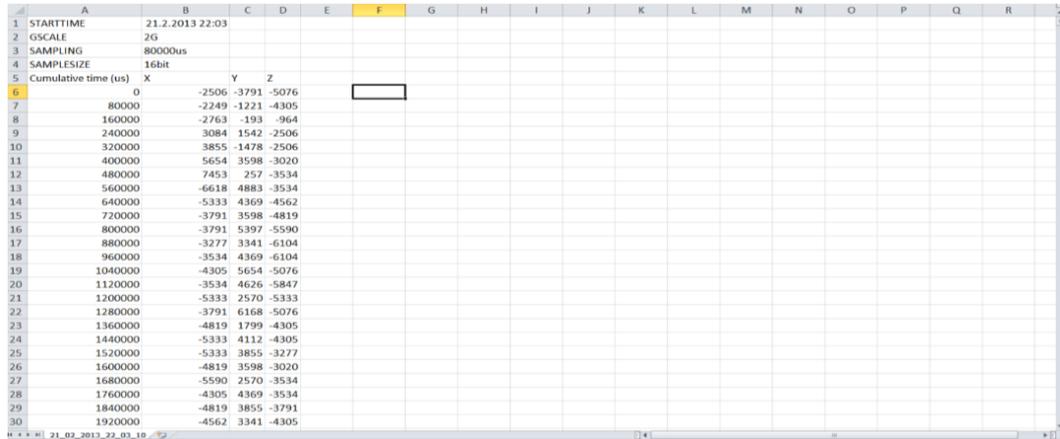


Figure 1. An example acceleration data file in Excel

The accelerometer measures acceleration in these directions:

- X: up – down
- Y: right – left
- Z: forward - backward

### Accelerometer settings

	Default mode (recommended)	Very high resolution sampling mode
<b>Sampling rate</b>	<b>12.5 Hz</b>	<b>50 Hz</b>
<b>G-scale</b>	<b>4 G</b>	<b>4 G</b>
<b>Sample size</b>	<b>8 bit</b>	<b>14 bit</b>
<b>Acceleration values</b>	<b>± 127</b>	<b>± 8192</b>
<b>Battery life</b>	<b>6 days</b>	<b>5 days</b>
<b>Memory storage</b>	<b>20 days</b>	<b>3 days</b>

The default setting means, in short, that each direction can get a value between -127 - +127, where the highest / lowest value is reached when the force of gravity in that direction is 4G or more.

For example, if you stand / sit still:

- X  $\approx$  -32 (force of gravity)
- Y  $\approx$  0
- Z  $\approx$  0

If you are absolutely sure that you want to use some other accelerometer settings than the recommended default settings in your research, you can change the settings in Firstbeat Uploader (Configure device-> Advanced settings-> Accelerometer settings). Remember that the higher resolution sampling mode use more memory and battery.