

WEARABLE BIOSENSOR MONITOR TO SUPPORT AUTONOMOUS CREW HEALTH AND READINESS TO PERFORM

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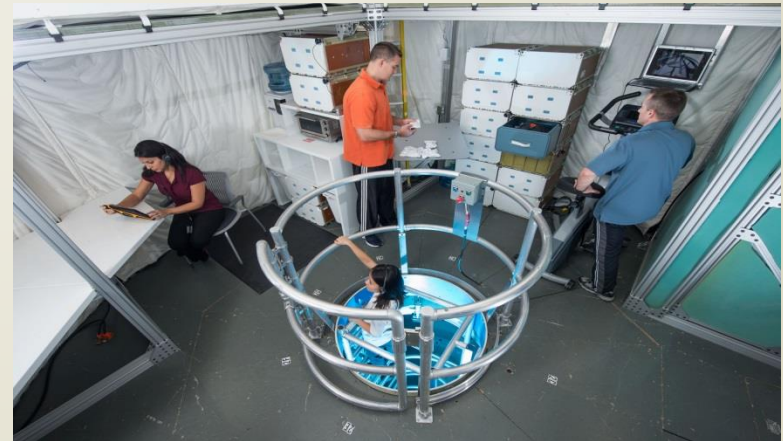
Human Exploration Research Analog (HERA)



HERA is a two-story habitat that includes a simulated airlock and hygiene module located in Building 220 at NASA JSC. It represents an analog for simulation of isolation, confinement, and remote conditions of mission exploration scenarios.



1st Floor



2nd Floor

Goal

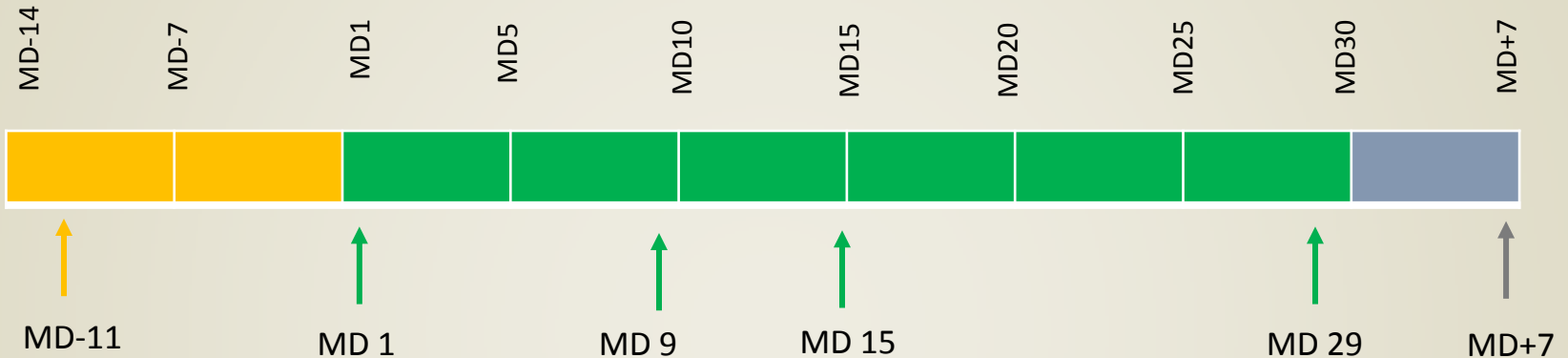
To evaluate and validate a prototype biosensor monitoring system (Astroskin) in collaboration with the Canadian Space Agency (CSA). Test of the Astroskin system during HERA flight analog studies will elevate the TRL from 5 to 6. CSA and NASA have mutual interests in advancing both biosensor monitoring capability and medical decision support software analytics based on biosensor and other medically relevant data. This effort provides foundational work for exploration missions in the areas of medical data architecture, clinical decision support and biosensor systems development.

Specific aims:

- To evaluate usability and performance of the Astroskin on ambulatory crew during 30-day HERA missions
- To obtain baseline data used for further development of algorithms and tools that facilitate decision making for medical support (e.g., personal fitness evaluations, diagnosis of sick or injured crew)
- To demonstrate performance of wireless Bluetooth technology in a flight analog environment

* In October 2016, CSA and NASA have signed an Implementing Arrangement (IA) for the evaluation of a wearable biosensor monitoring system and related technologies

HERA Campaign 3 Timeline Astroskin Data Collection Overview



Data Collection

Pre Mission

- MD- 11
Activity: train/monitor/survey
Duration: 1 hr/24 hrs/15 min
Crew: 4

In Mission

- MD 1, 9, 15, 29
Activity: monitor/survey
Duration: 24 hrs/15 min
Crew: 4

Post Mission

- MD+ 6
Activity: monitor/survey
Duration: 24hrs/15 min
Crew: 4

HERA Campaign 3

- 4 missions
- mission duration - 30 days
- crew complement each mission – 4 (men, women, and/or mixed gender)

Study participants

- 9 men and 7 women
- mean age: 36.8, sd: 7.07

Procedures

Pre Mission Baseline (MD-11)

- crew training on Astroskin hardware/software
- continuous physiological monitoring -24 hours
- crew survey on usability and performance – mobile device

In Mission (MD1, MD9, MD15, MD29)

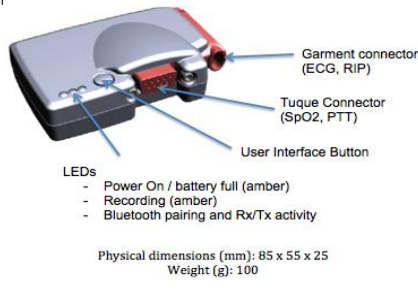
- continuous physiological monitoring -24 hours
 - ✓ high workload day – 130% of nominal load (nominal load = 6.5hrs)
 - ✓ low workload day – 70% of nominal load
 - ✓ submaximal exercise on cycle ergometer -30 minutes on 2 mission days
- crew data verification using onboard mobile device – 4x each day
- crew survey on usability and performance- mobile device

Post Mission Baseline (MD+7)

- continuous physiological monitoring -24 hours
- crew survey on usability and performance – mobile device
- crew debrief

Note: Astroskin data were downloaded to crew laptops after each 24 hour monitoring session and later transferred to FAP server for access by PI team. No live data streaming to PI team or FAP support personnel in MCC.

Astroskin Garment and Plug-in Module



Description

- Wearable garment-based continuous physiological monitoring system, reusable (washable)
- Secure wireless communication
- Physiological events detection & alerts (planned for future version)
- Decision support capabilities (planned for future version)

Sensors (embedded)

- 3-axis accelerometer (Activity levels)
- ECG (3-lead) - QRS detection, HR, HR variability
- Respiration (Resp rate, Resp volume, ¹ Minute ventilation)
- Oxygen saturation (SPO₂)
- Systolic Blood pressure ¹
- Skin temperature

¹ Calculated value

Sample Questions on Crew Survey

In general, how comfortable was the Astroskin garment?

1 2 3 4 5

Very uncomfortable

Very comfortable

Comments (if applicable):

In general, how comfortable was the Astroskin headband or toque?

1 2 3 4 5

Very uncomfortable

Very comfortable

Comments (if applicable):

How well did the Astroskin garment fit?

1 2 3 4 5

too loose

Too tight

Comments (if applicable):

Did you experience any skin irritation as a result of wearing the Astroskin garment or headband (or toque)?

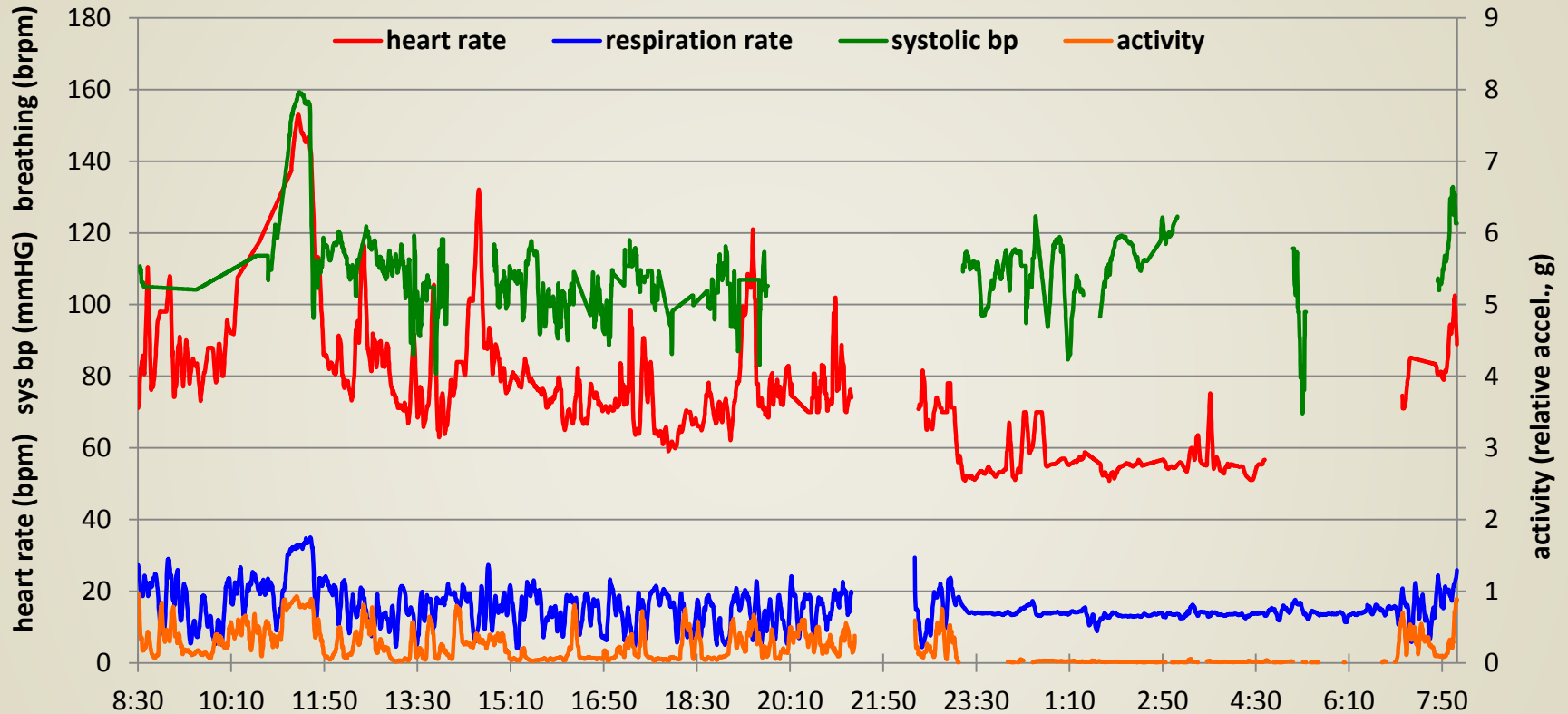
1 2 3 4 5

Significant skin irritation

No skin irritation

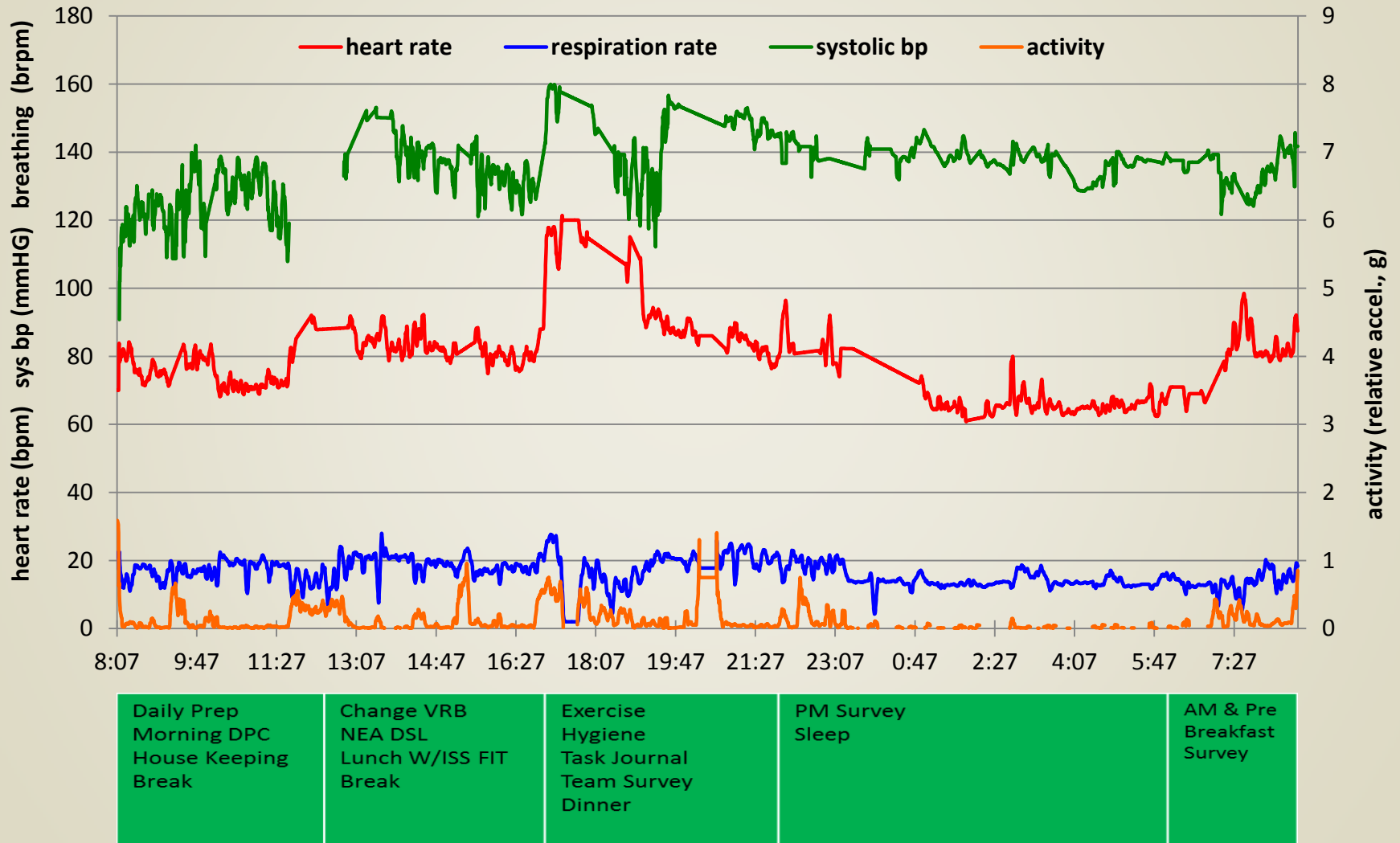
Comments (if applicable):

Subject B (female) High Workload Day

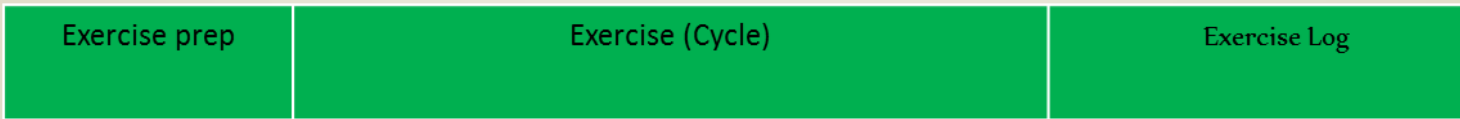
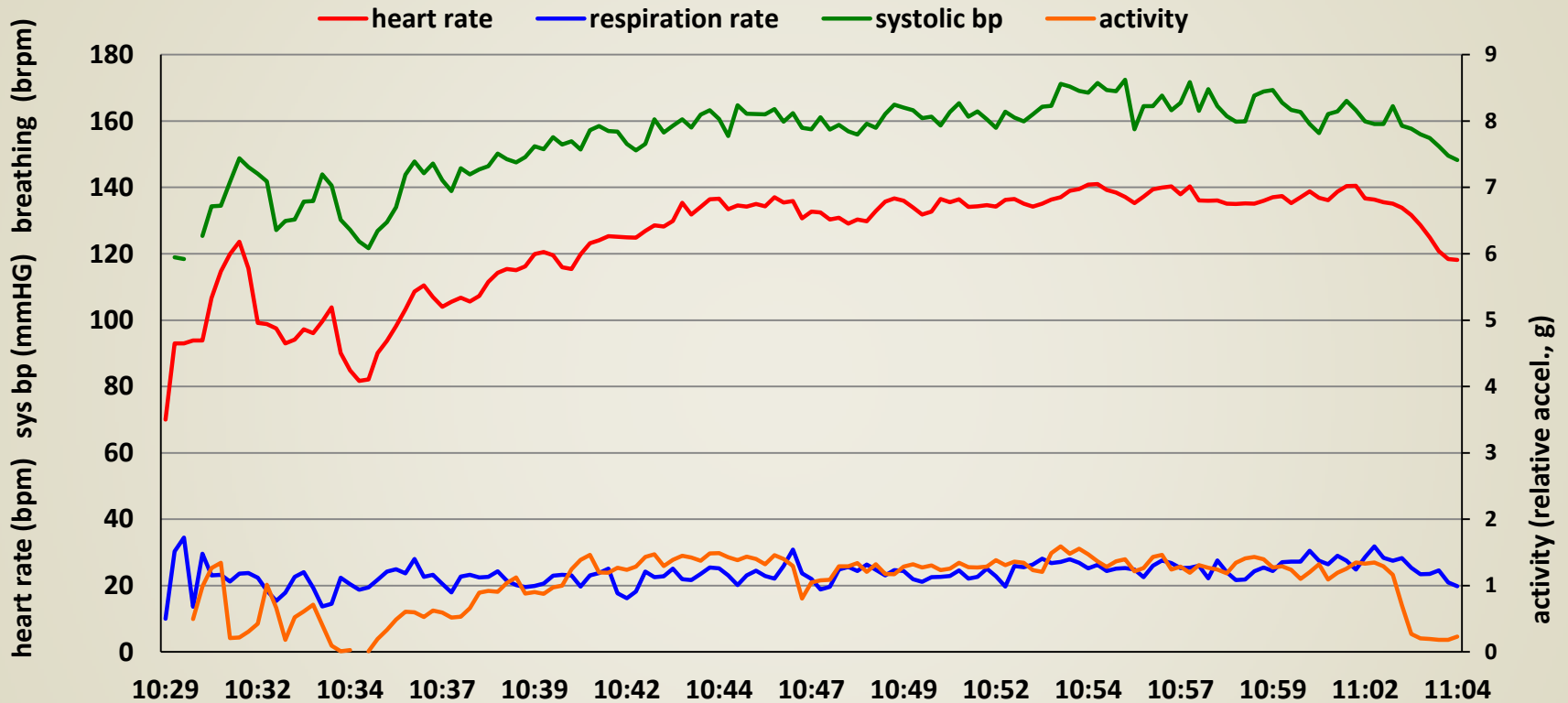


Daily Prep EV SMP Rover PMC	Exercise Change VRB	Break Lunch W/ISS NEA DSL Multiteam task	EV SMP PFC Microbime Evening DPC Dinner W/ISS	Survey Pre Sleep Act	Food Function Survey PM survey Sleep	AM Survey Saliva (Alfano)
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Subject C (male) Low Workload Day

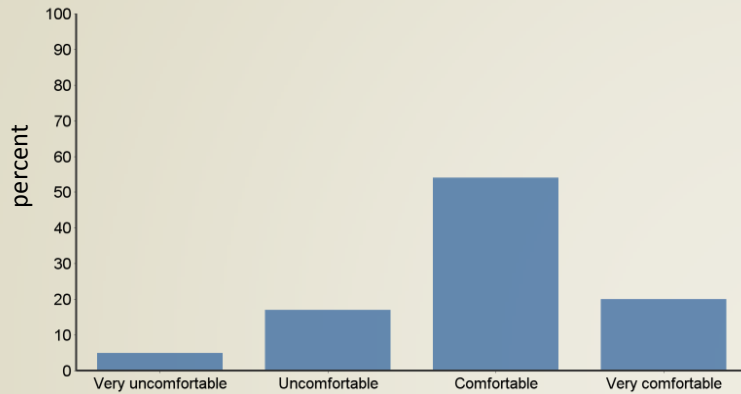


Subject A (male) Sub-Maximal Ergometer Exercise

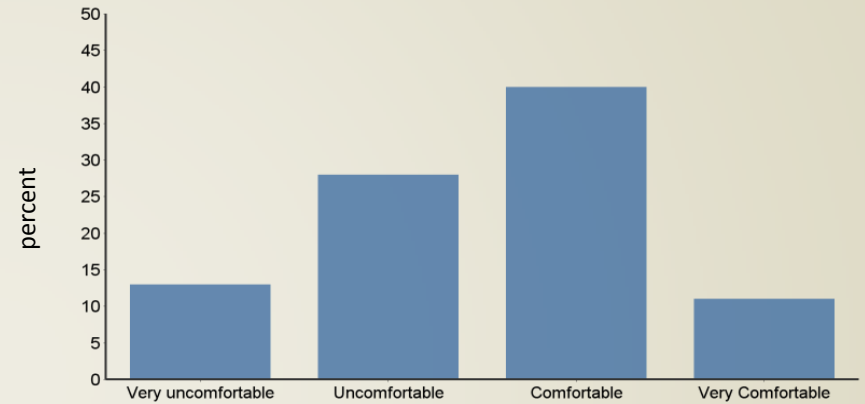


Crew Survey Sample Questions- 16 Subjects (Missions 1-4)

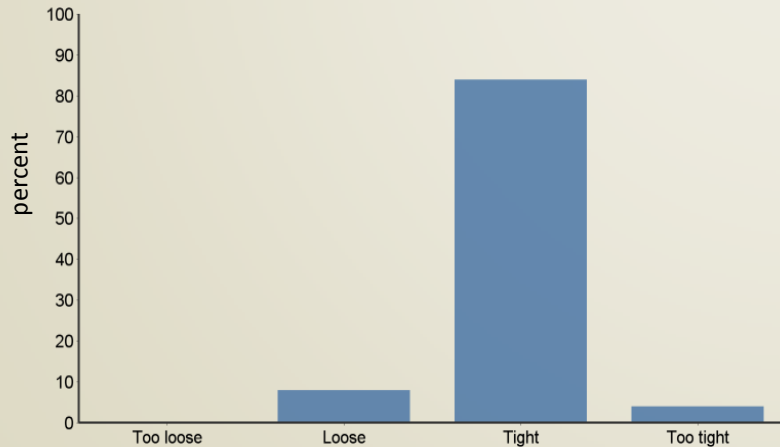
In general, how comfortable was the Astroskin garment?



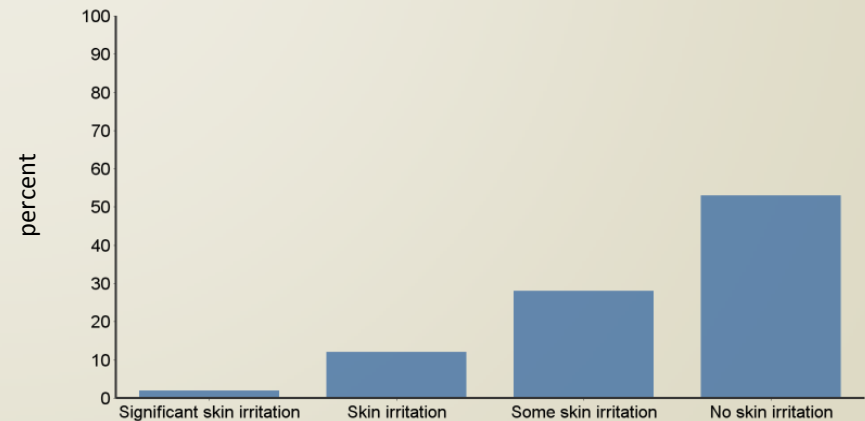
In general, how comfortable was the Astroskin headband?



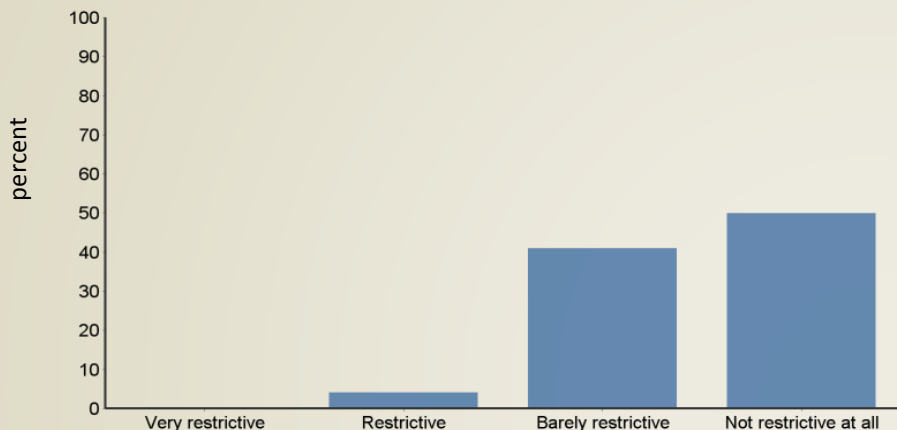
How well did the Astroskin garment fit?



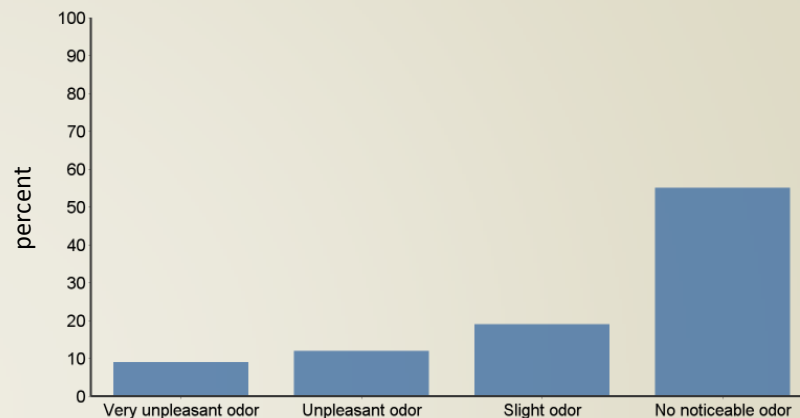
Skin irritation as a result of wearing the Astroskin garment or headband (or toque)



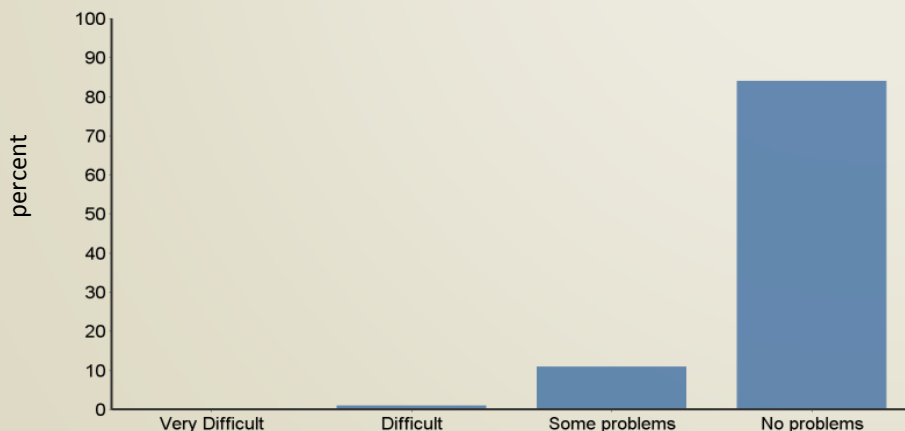
Did the Astroskin garment or device inhibit or restrict your normal movements?



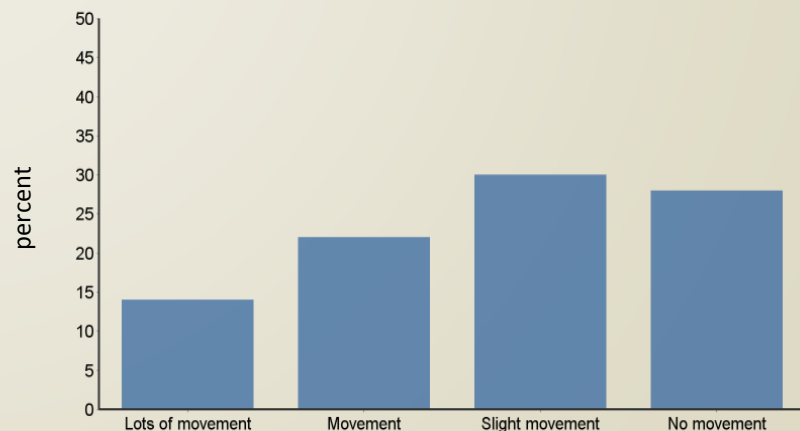
Unpleasant odors from the garment?



Did you have any problems donning the Astroskin garment?



Did you ever notice any repositioning or movement of the garment or sensors as a result of body movements?



Lessons Learned

- real-time data streaming via Bluetooth to onboard mobile device significantly reduces battery life resulting in less than 24-hour recordings
- current software for real-time data streaming does not store data on the mobile device
- intermittent failures downloading data to crew laptops due to interface cable and/or software
- inability to view streaming data is a risk to studies in the analog environment and may result in signal loss or poor signal quality
- current prototype garment design is less than optimal for female crew which resulted in movement of ECG sensors and poorer signal quality
- washability of garment is a potential issue for extended duration missions requiring cleaning options or stowage of multiple garments
- SpO2 sensor/headband causes significant discomfort when worn for 24 hour period

Conclusions

- biosensor data was acquired which will be used for algorithm development to improve signal processing, vital sign notification of signal loss, signal quality and anomalous events, and to develop tools to facilitate decision making for medical support
- signal quality of biosensor data was acceptable (in most cases) during exercise sessions
- 24-hour ambulatory monitoring was possible when data are stored on the embedded Astroskin module (no real-time streaming)
- real-time data streaming requires higher capacity battery and/or lower power Bluetooth transmitter
- analog setting has helped us better understand some constraints and requirements related to the design and use of a biomonitors system (e.g., interference from other equipment)
- crew input from the surveys provided us with useful insights on how to improve the garment design
- an improved version of Astroskin is scheduled to fly on ISS in 2018 based on this study's lessons learned

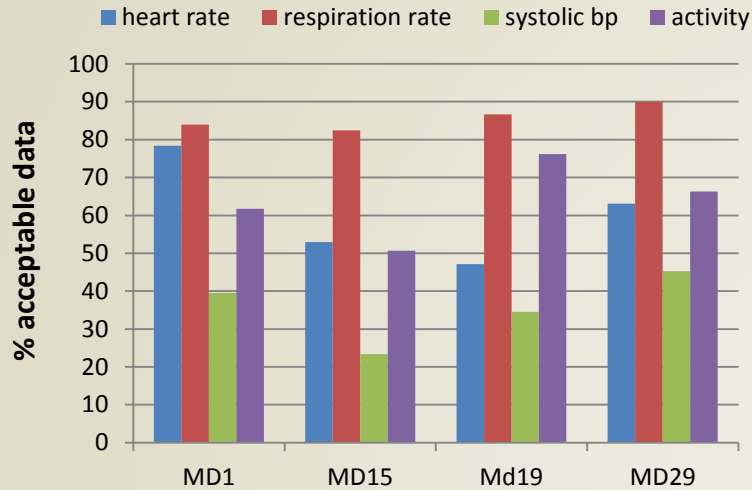
Future Plans

- CSA is developing wireless biomonitors system (not shirt-based) using small, unobtrusive stand-alone patch sensors
- sensors communicate via Bluetooth Low Energy with sensor interface unit (SIU) located on or off-body
- data from the SIU will integrate with a Medical Data Architecture system under development by NASA Ames that will process and store data in a common format and provide a data management capability for medical operations
- sensors (maximum of 6)
 - ✓ measurements: ECG, heart rate, oxygen saturation and PPG, skin temperature, body movement (3-axis), stress level: galvanic skin response, systolic blood pressure derived from PTT using O2 and ECG data
 - ✓ low profile (maximum 5mm height)
 - ✓ powered by lithium coin cell battery
 - ✓ electronic circuit encapsulated to protect from sweat and water ingress
 - ✓ continuous monitoring over a period of 7 days without replacement
 - ✓ 1 RIP band for respiratory parameters: rate and volume
- Conduct a ground-based human-in-the-loop technology demonstration of the wireless sensor system during activity relevant to exploration missions to validate its operational feasibility for long-term health monitoring

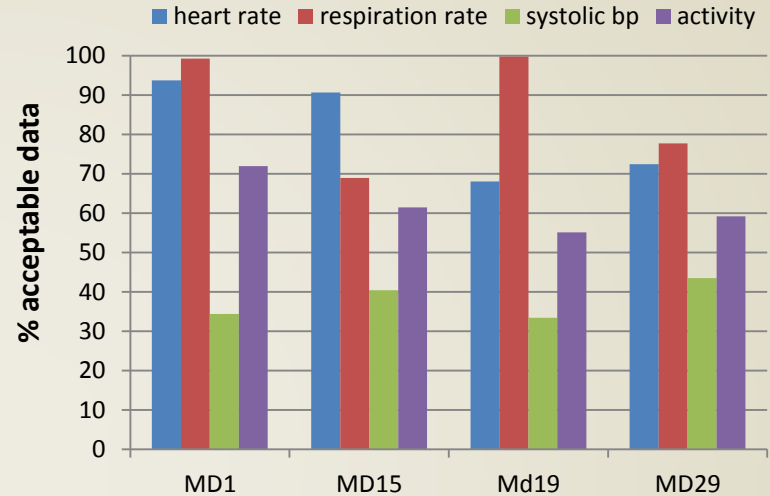


BACK UP SLIDES

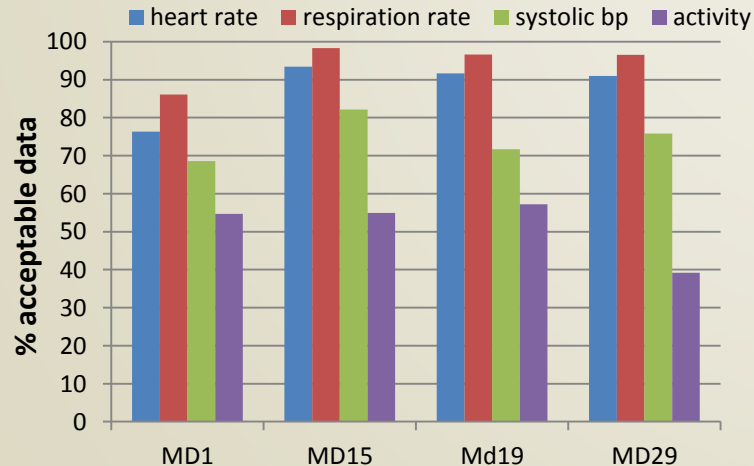
Mission 1 All Crew



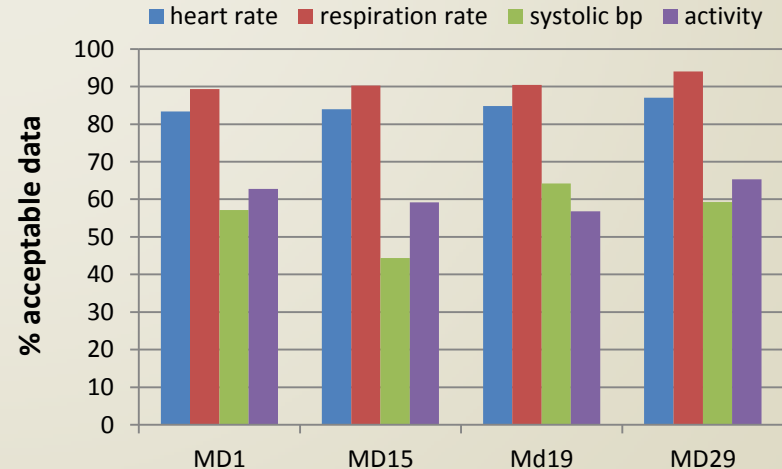
Mission 2 All Crew



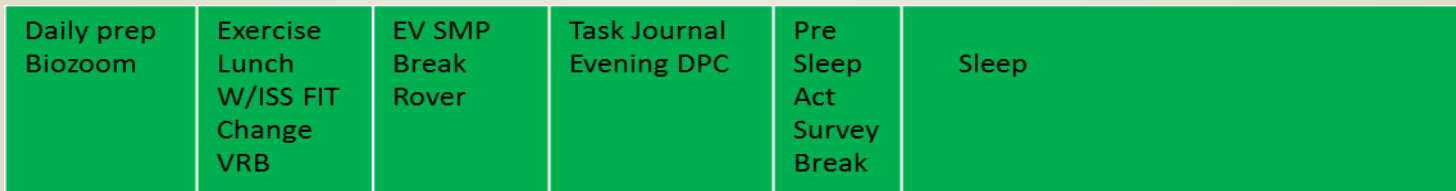
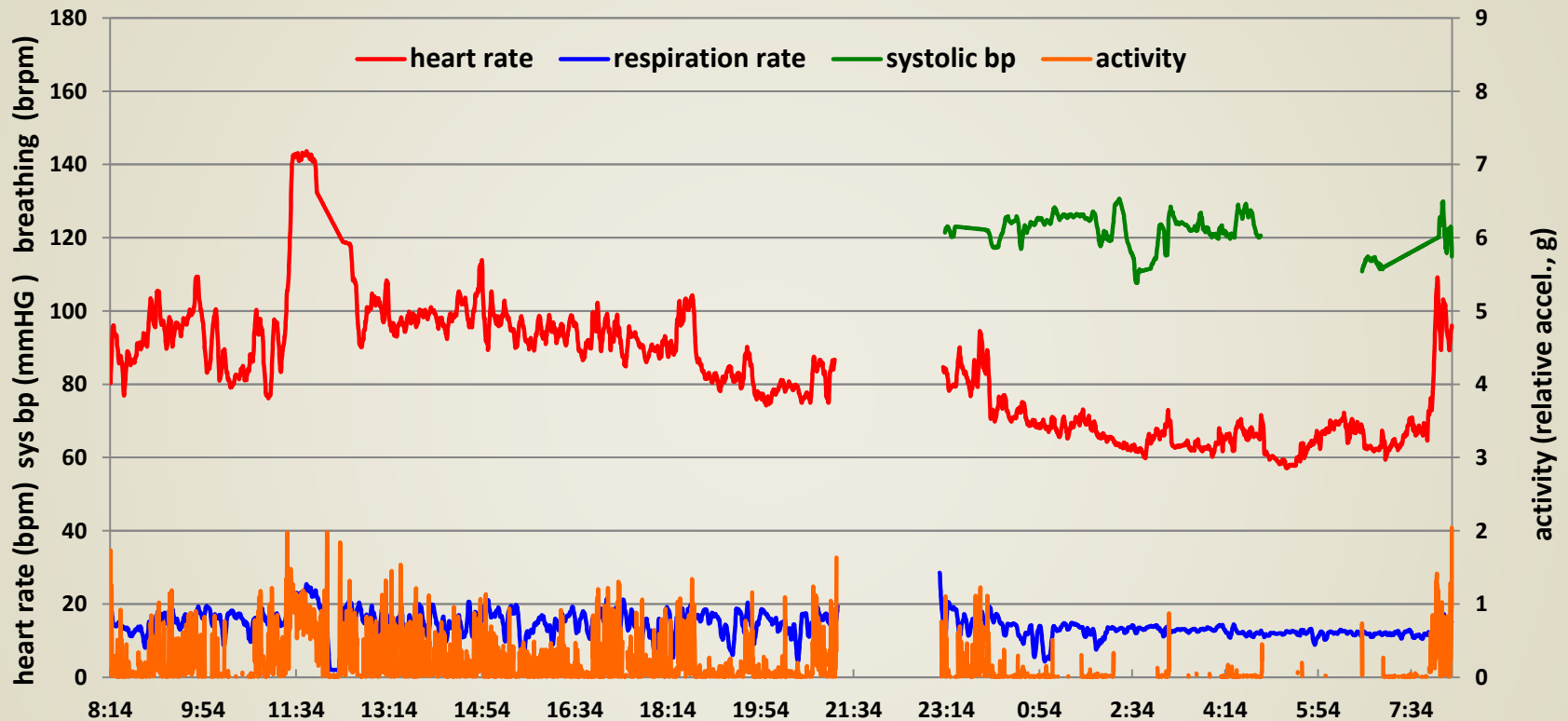
Mission 3 All Crew



Mission 4 All Crew

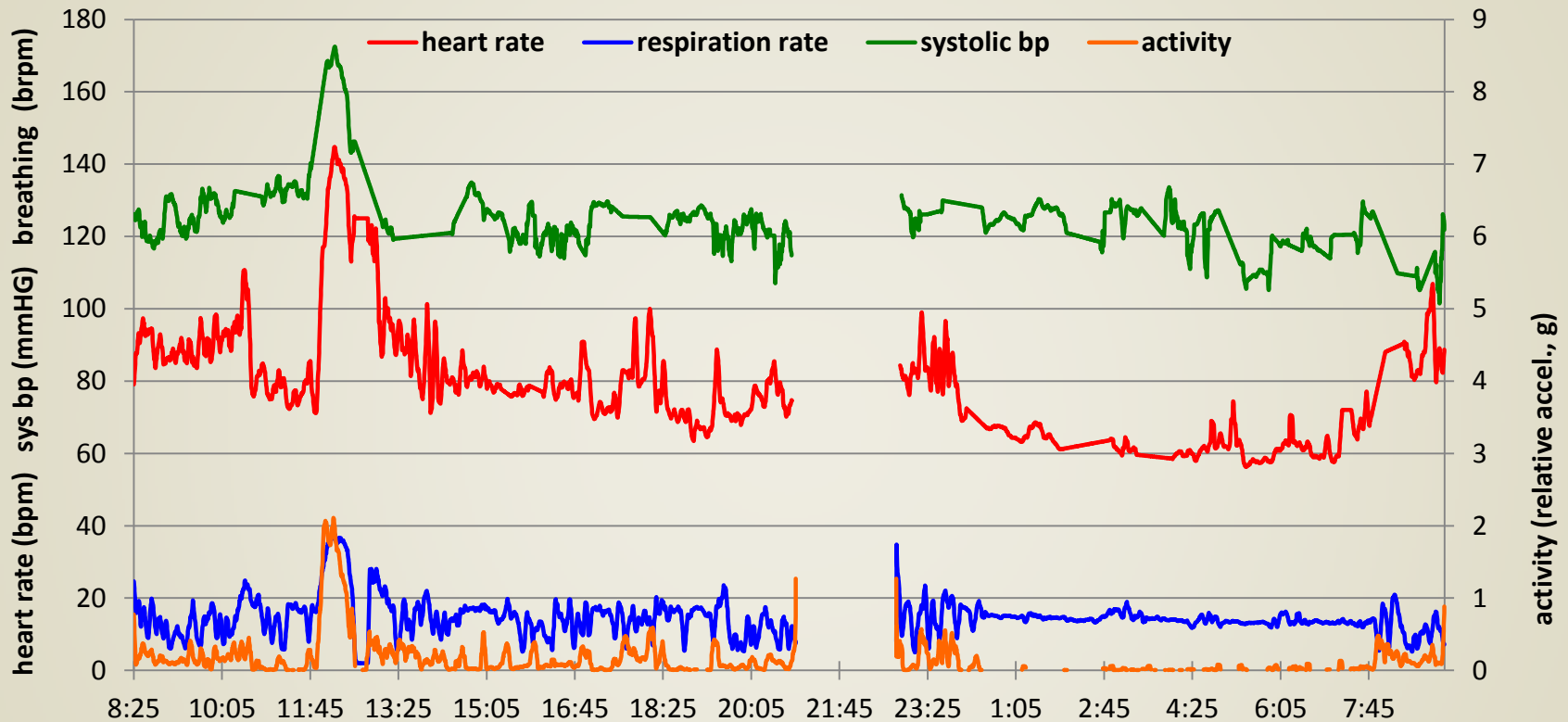


Subject A (male)- High Workload Day



* 15 second moving average

Subject D (female) Low Workload Day



Daily prep Morning DPC EV SMP Biozoom	Exerise Change VRB NEA DSL	Lunch Break Change VRB	Break work hazard scale	Dinner W/ISS FIT pre sleep Activities	Sleep	AM & post brakfast Survey
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Subject D (female) Sub-Maximal Ergometer Exercise

