Wireless Health

Case Study: Wireless Health

- Category : Utilitarian
- Requirements: Continuous monitoring, Wearable – part of a plaster attached to the chest, unobtrusive, automatic download of data, no recharging – 6 mo battery life, no on-off switch
- Users: Patients, GP, Nurses, Hospital consultants
- Sensors: 3-D Accelerometer at 12.5 Hz
- Actuators: Visual display on tablet/smart phone
- Data Analysis: Calculate respiratory rate from sensor data which can vary between 8 to 50 breaths/minute
- Wireless protocol: Bluetooth LE to tablet/phone, WLAN to server

Identify unmet healthcare needs

Engage with the stakeholders

Create strong evidence base

Unmet Healthcare Need

Managing COPD

- Patients reported symptoms – unreliable and inaccurate
- Indicators of exacerbation
  - Increase in breathlessness
  - Changes in respiratory rate and breathing pattern
  - Reduction in activity
- Pulmonary rehabilitation to reduce recurrence of exacerbation

Continuous remote monitoring of Respiration and Activity

Unmet Healthcare Need

- Respiration – one of the four vital signs monitored in a SEWS chart
- Identify early exacerbation in COPD
- Support pulmonary rehabilitation post exacerbation

“Monitoring of patients with COPD at home may help NHS boards avoid costs of £1,000 per patient per year”

Source : A Review of Telehealth in Scotland, 2011

COPD Monitoring Service

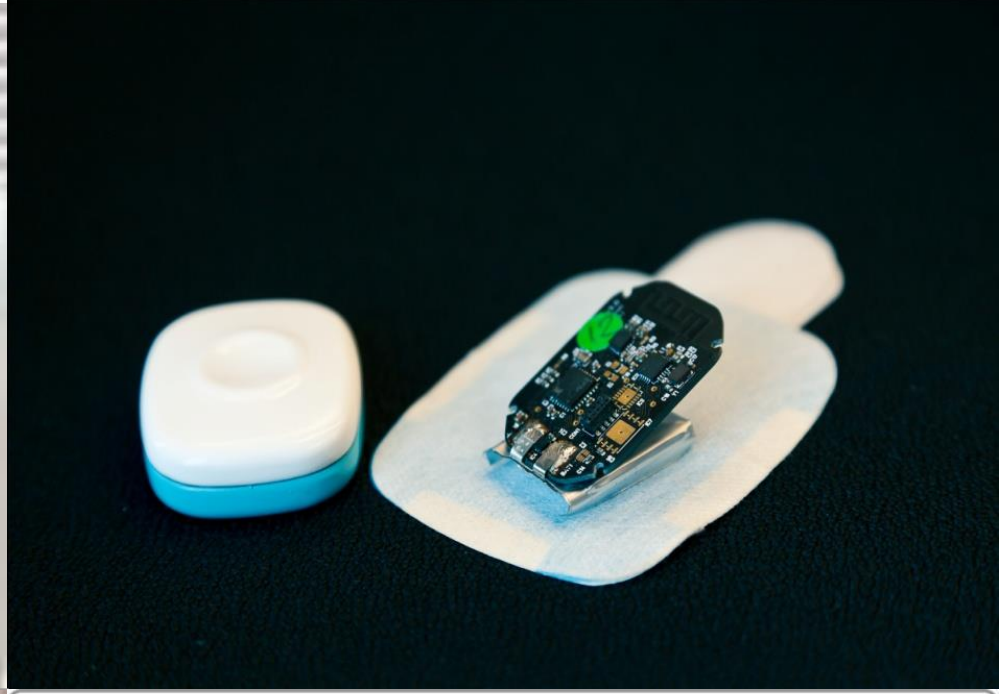
- Daily reports summarising hourly trends
- Option to access historical data
- Respiratory rate, respiratory effort/flow, activity
- Remote examination of patient's breathing in real-time
- Predictive models for exacerbation

Engagement with stakeholders

Focus Group

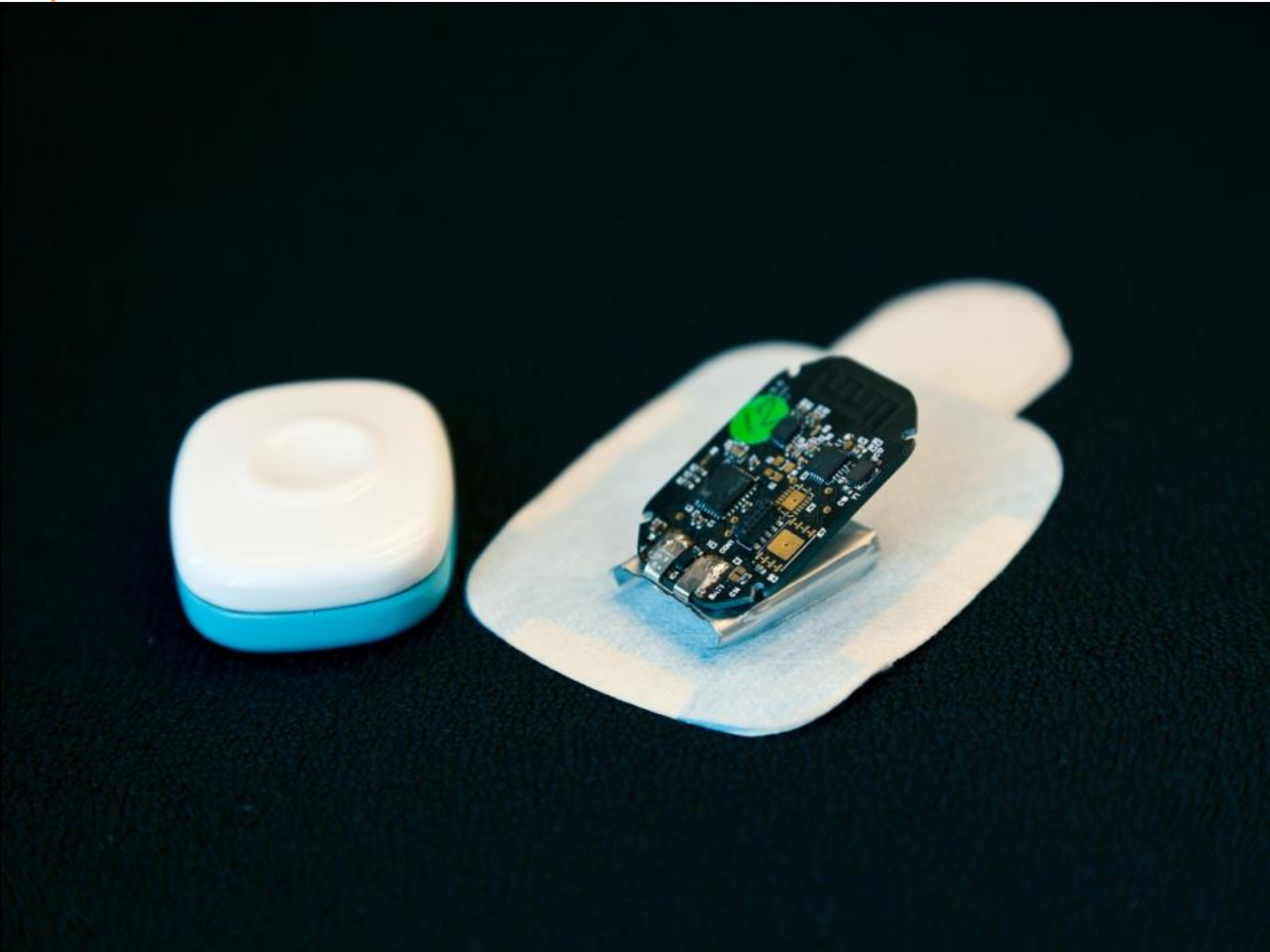
Patients, Carers, Hospital Consultants, General Practitioners, Nurses

- Continuous (24/7) monitoring
- Wearability issues
- No on/off switches
- No battery recharging
- Automatic download of data



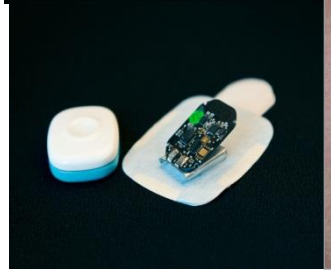
Patient-centric design

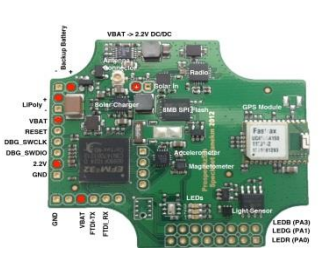
- Long-term wear
  - Light-weight - 17gms (incl. battery)
  - Unobtrusive - 4.5 x 3.7 x 1.3 cm
  - Battery lifetime - 6 months
- Ease of use & no manual intervention
  - No recharging of batteries
  - Data stored on wireless patch and downloaded to the base-station when within range
  - Always on

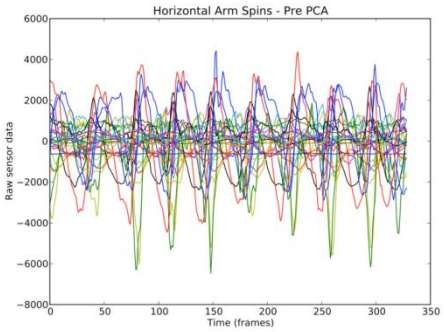


- Specks: miniature devices combine sensing, processing and wireless networking
- Wireless patch for measuring respiratory rate, respiratory effort and activity
- Continuous remote monitoring which transmits data to a secure server via fixed line broadband connection or 3G cellular network

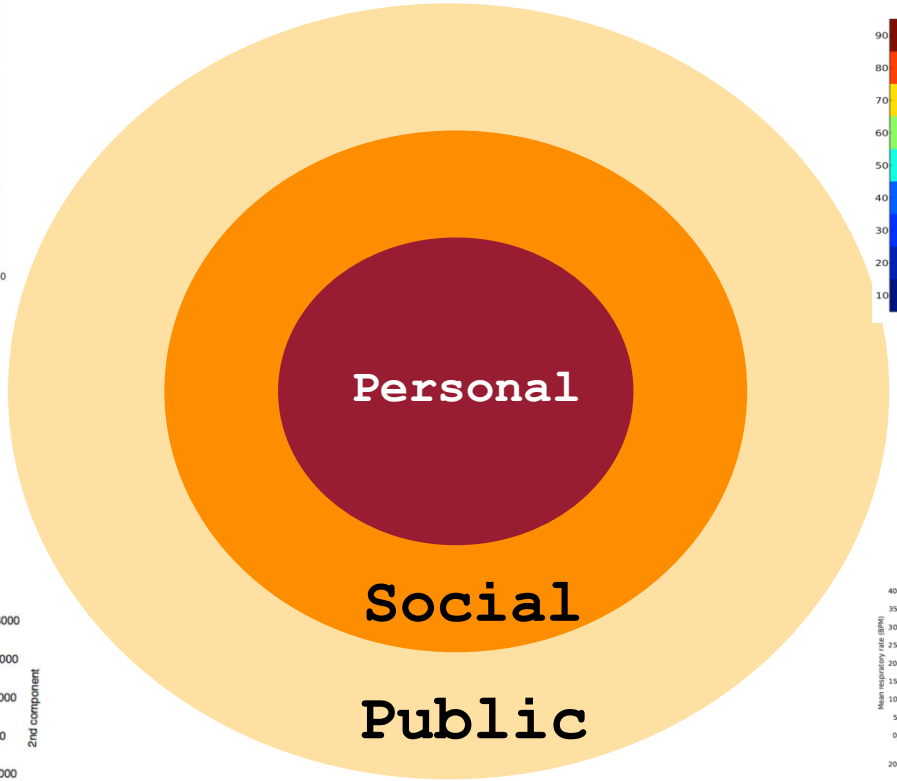


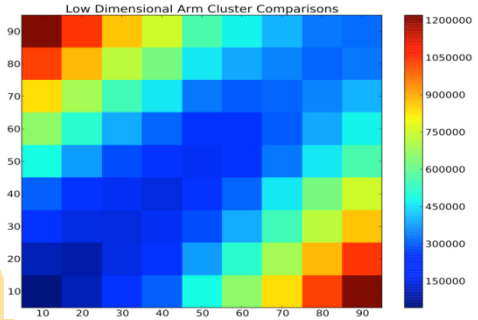






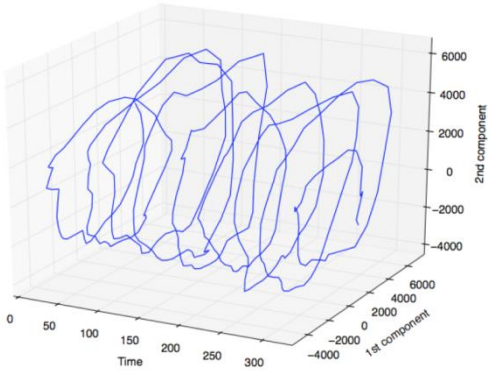
Sense – Learn -- Act

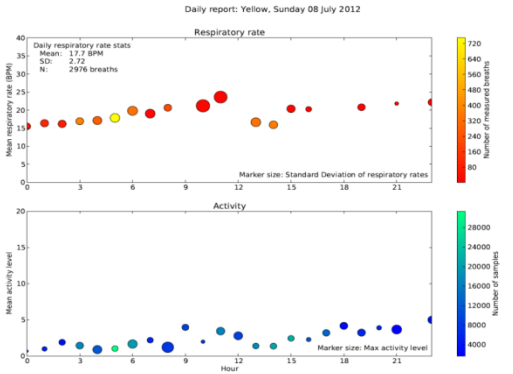




Computation

"Intelligence"

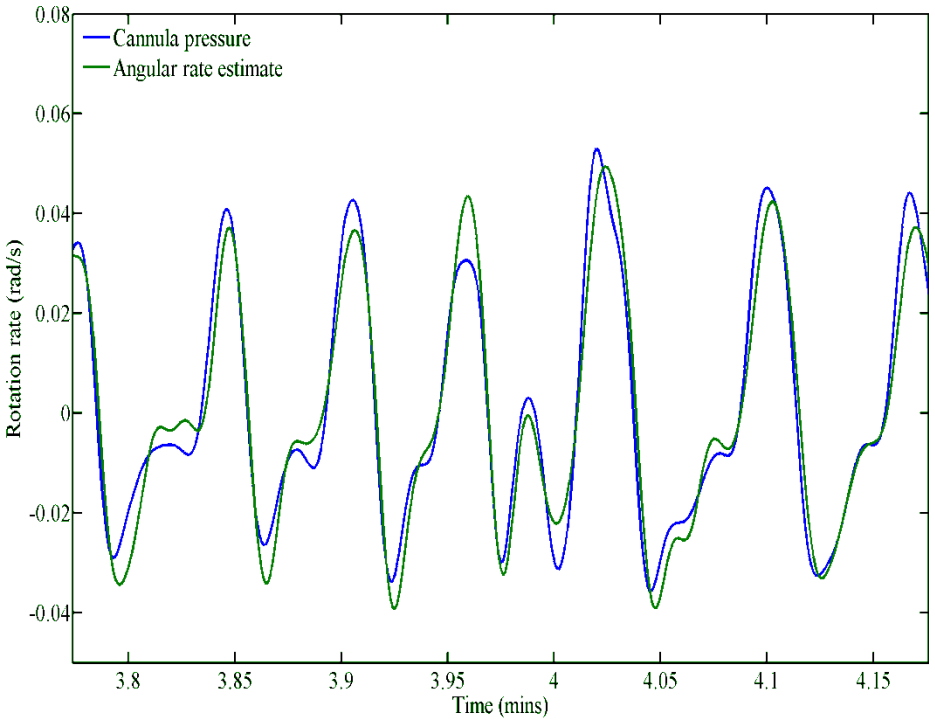


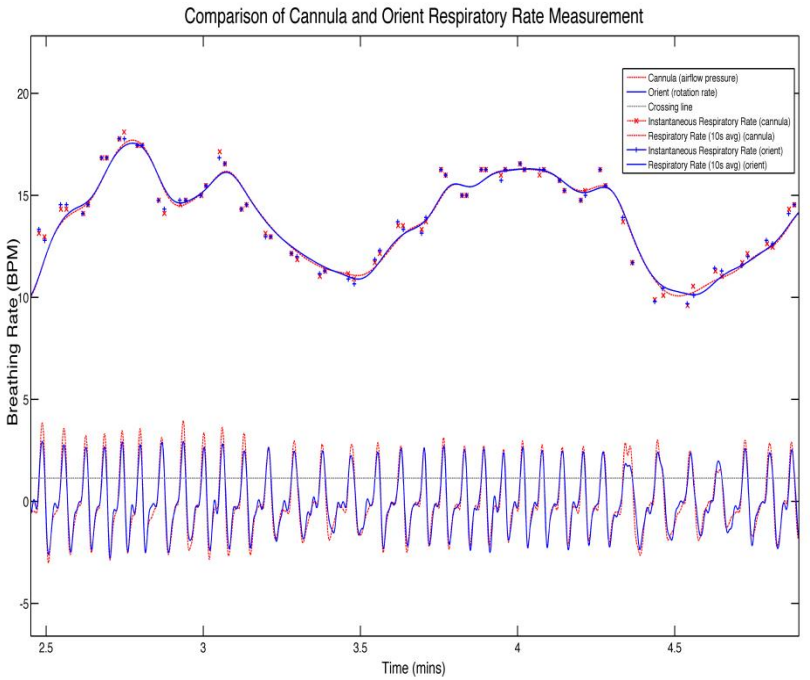


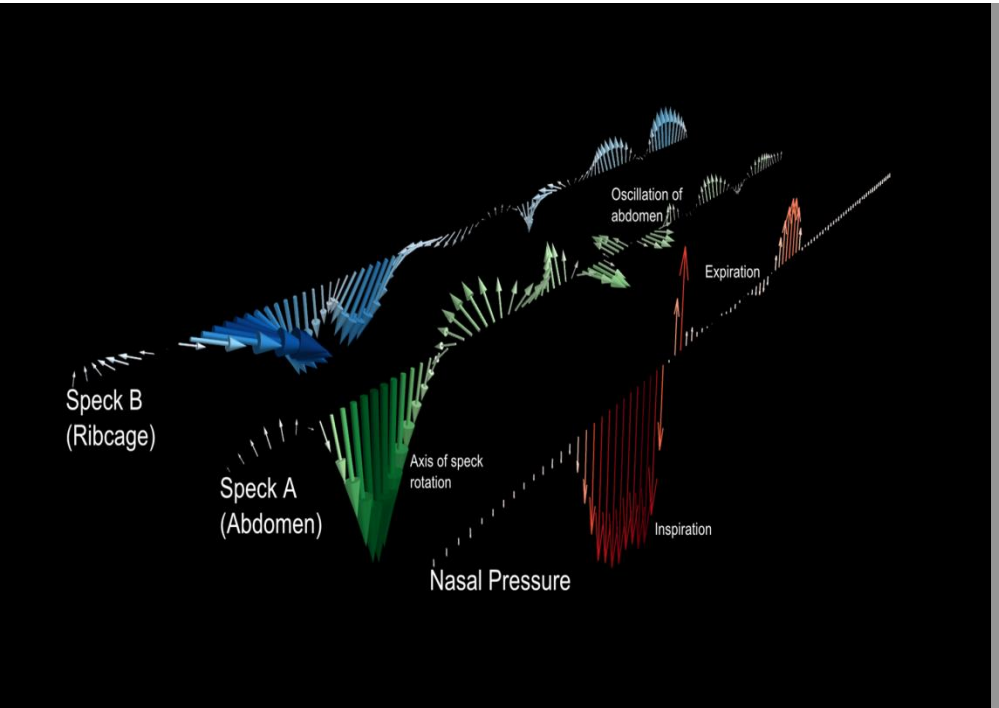
Communication

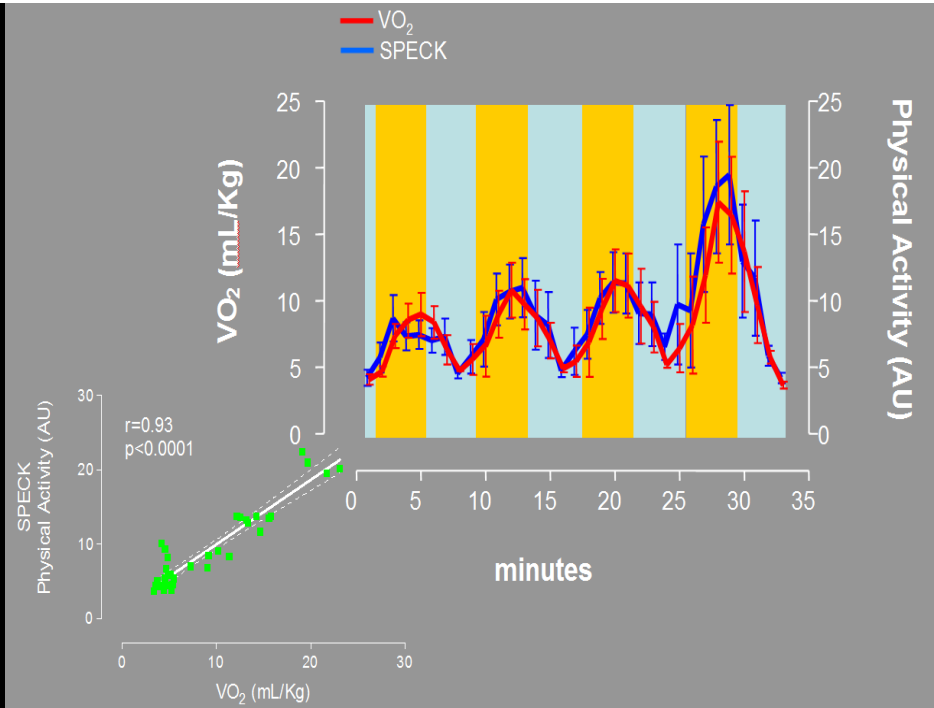
Speckled Computing

Evidence Base


Cannula pressure
Angular rate estimate
Rotation rate (rad/s)
Time (mins)


Comparison of Cannula and Orient Respiratory Rate Measurement
Cannula (airflow pressure)
Orient (rotation rate)
Crossing line
Instantaneous Respiratory Rate (cannula)
Respiratory Rate (10s avg) (cannula)
Instantaneous Respiratory Rate (orient)
Respiratory Rate (10s avg) (orient)
Breathing Rate (BPM)
Time (mins)


Oscillation of abdomen
Expiration
Speck B (Ribcage)
Speck A (Abdomen)
Axis of speck rotation
Inspiration
Nasal Pressure


VO2
SPECK
VO2 (mL/Kg)
Physical Activity (AU)
minutes
r=0.93
p<0.0001
SPECK Physical Activity (AU)
VO2 (mL/Kg)

Summary of results of clinical trials at RIE

248 hours of breathing were studied

Successful transmission 94% of the time

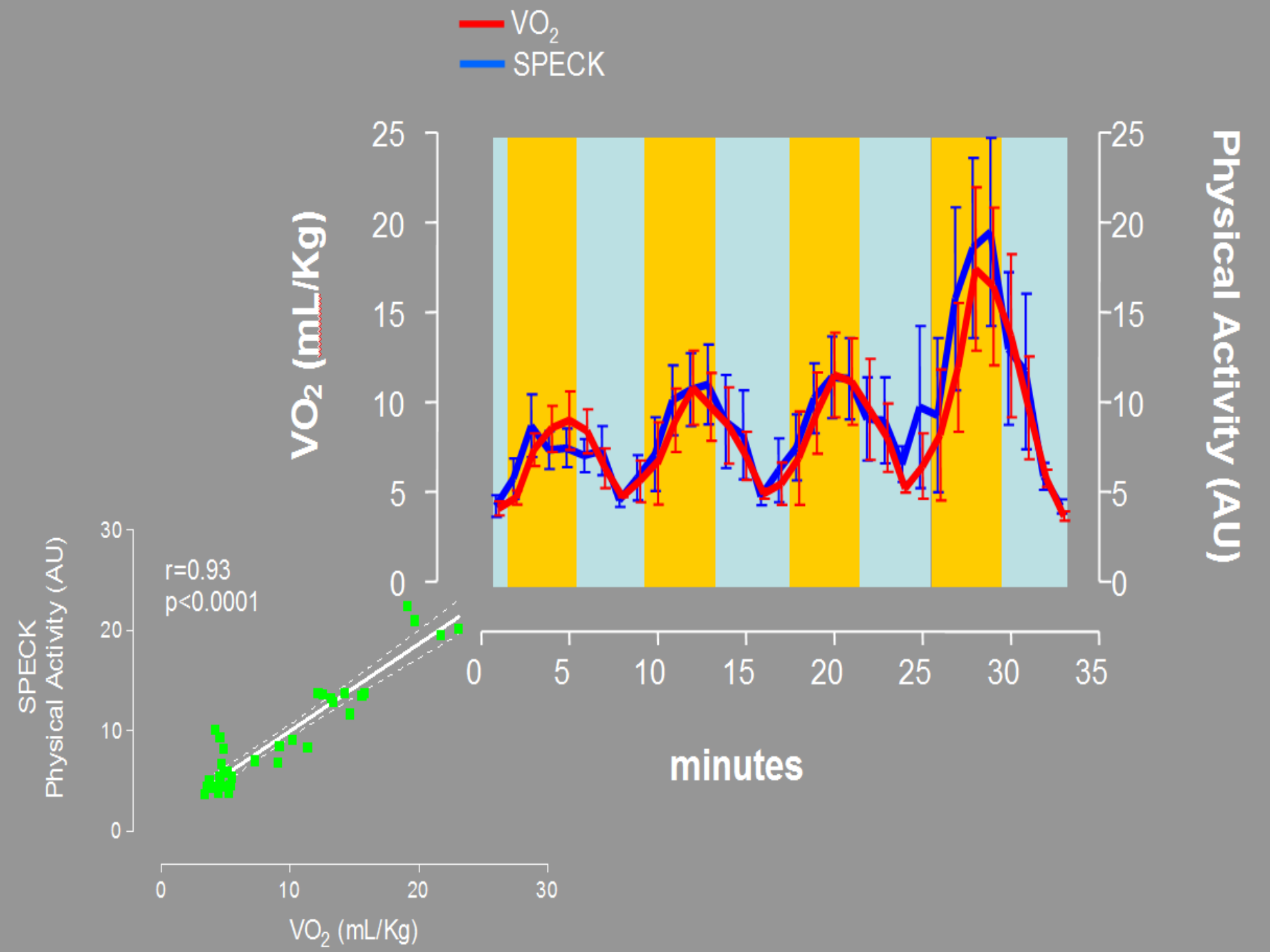
119,765 valid cannula breaths

105,416 matched to Orient breaths

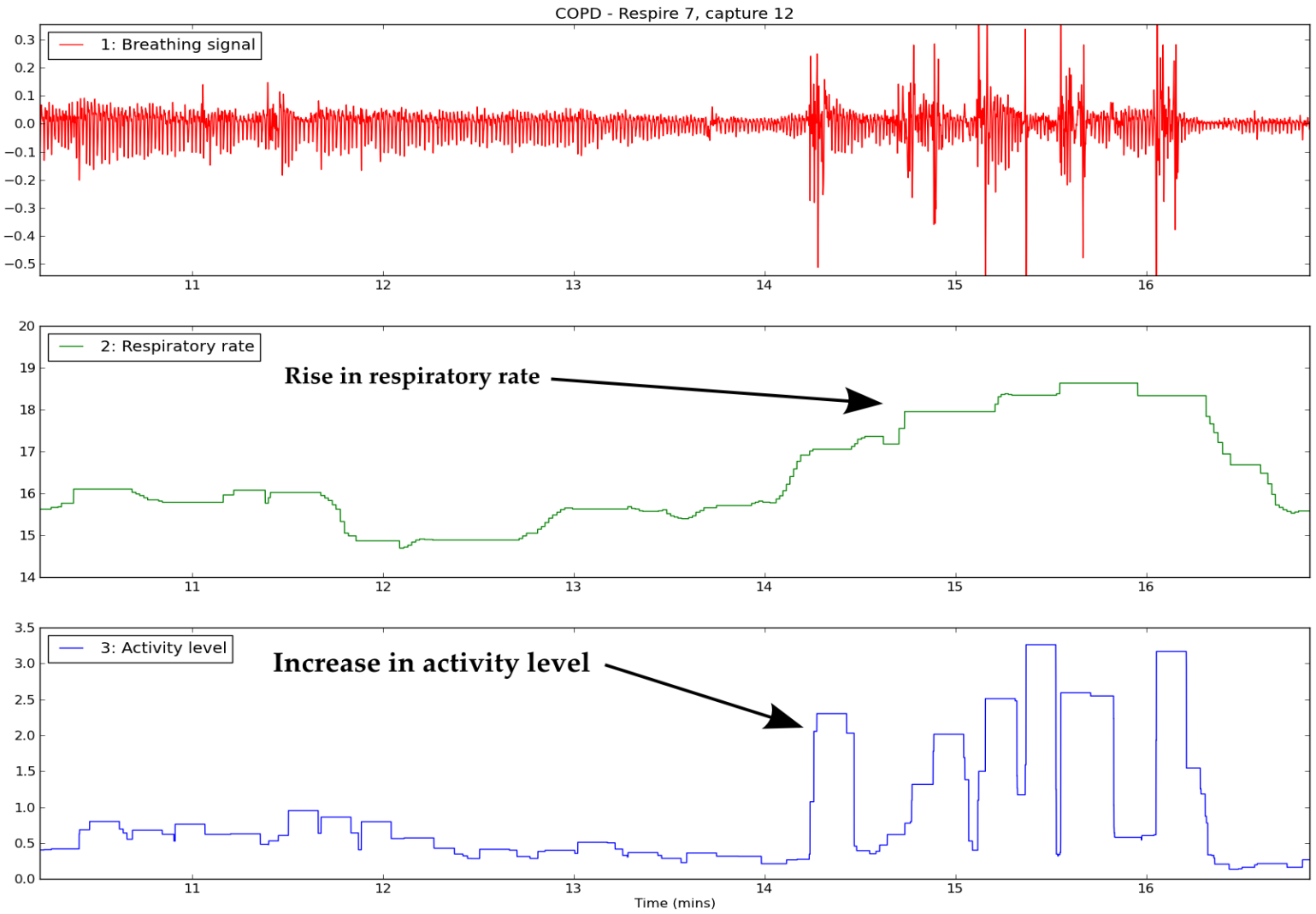
Instantaneous respiratory rates agree to within 2BPM for 86% of matched breaths

Mean absolute difference: 0.6BPM

A reliable measure of respiratory rate was possible in 95.4% of the 5 minute epochs


VO2
SPECK
VO2 (mL/Kg)
Physical Activity (AU)
minutes
0
5
10
15
20
25
30
35
r=0.93
p<0.0001
SPECK
Physical Activity (AU)
VO2 (mL/Kg)

Simultaneous RR/Activity in COPD patient

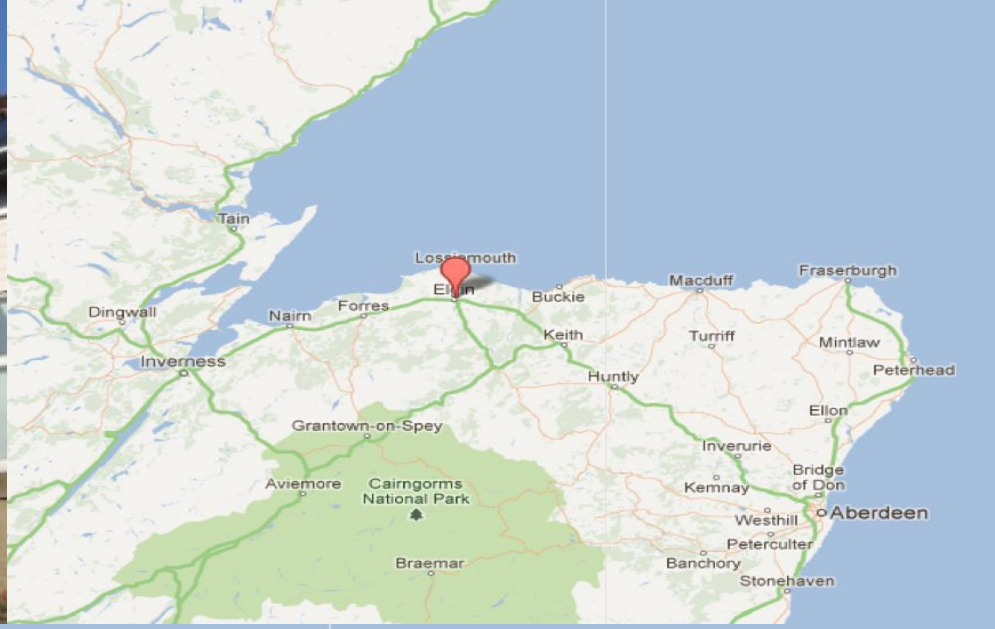


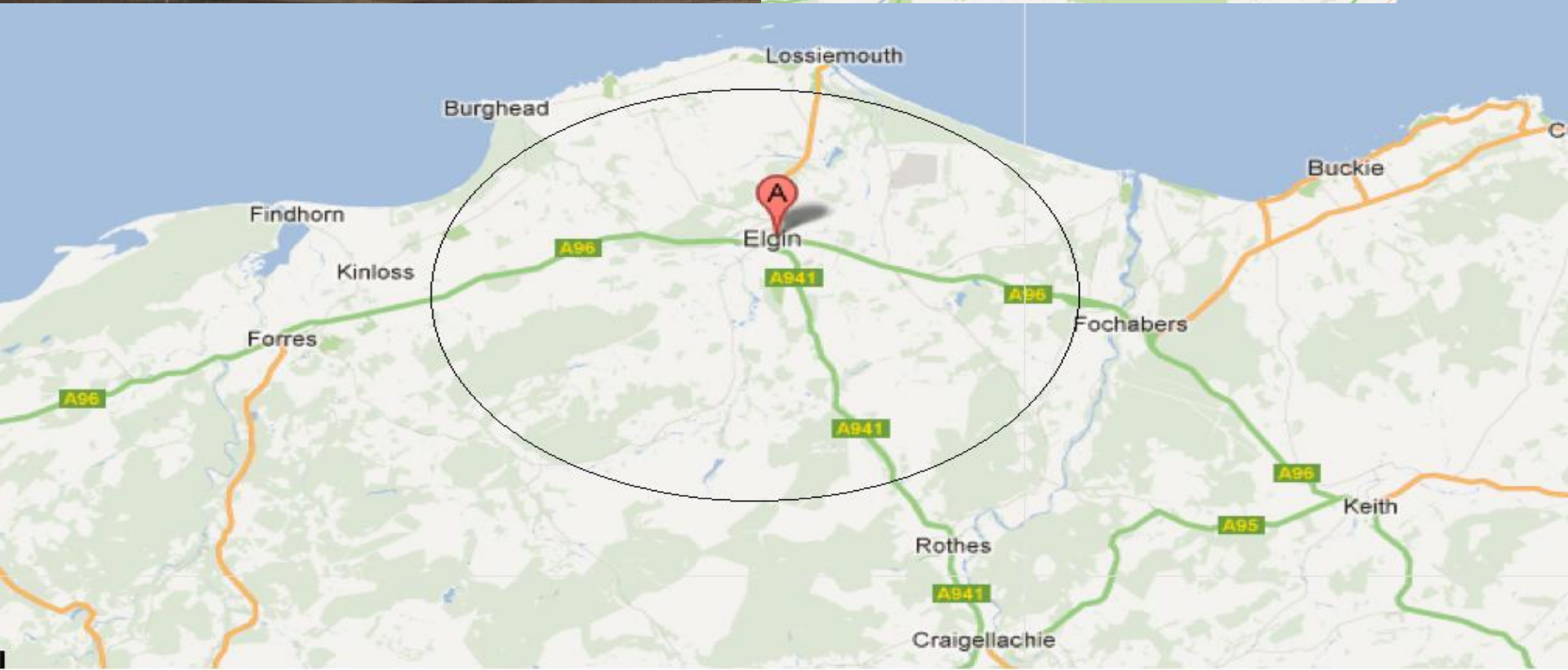
The Moray Study

- Study use of wireless respiratory and activity monitoring in a community setting
- Evaluate impact on the stakeholders: patients, clinicians, nurses, health authority
- Confirm usefulness of data in Primary care setting

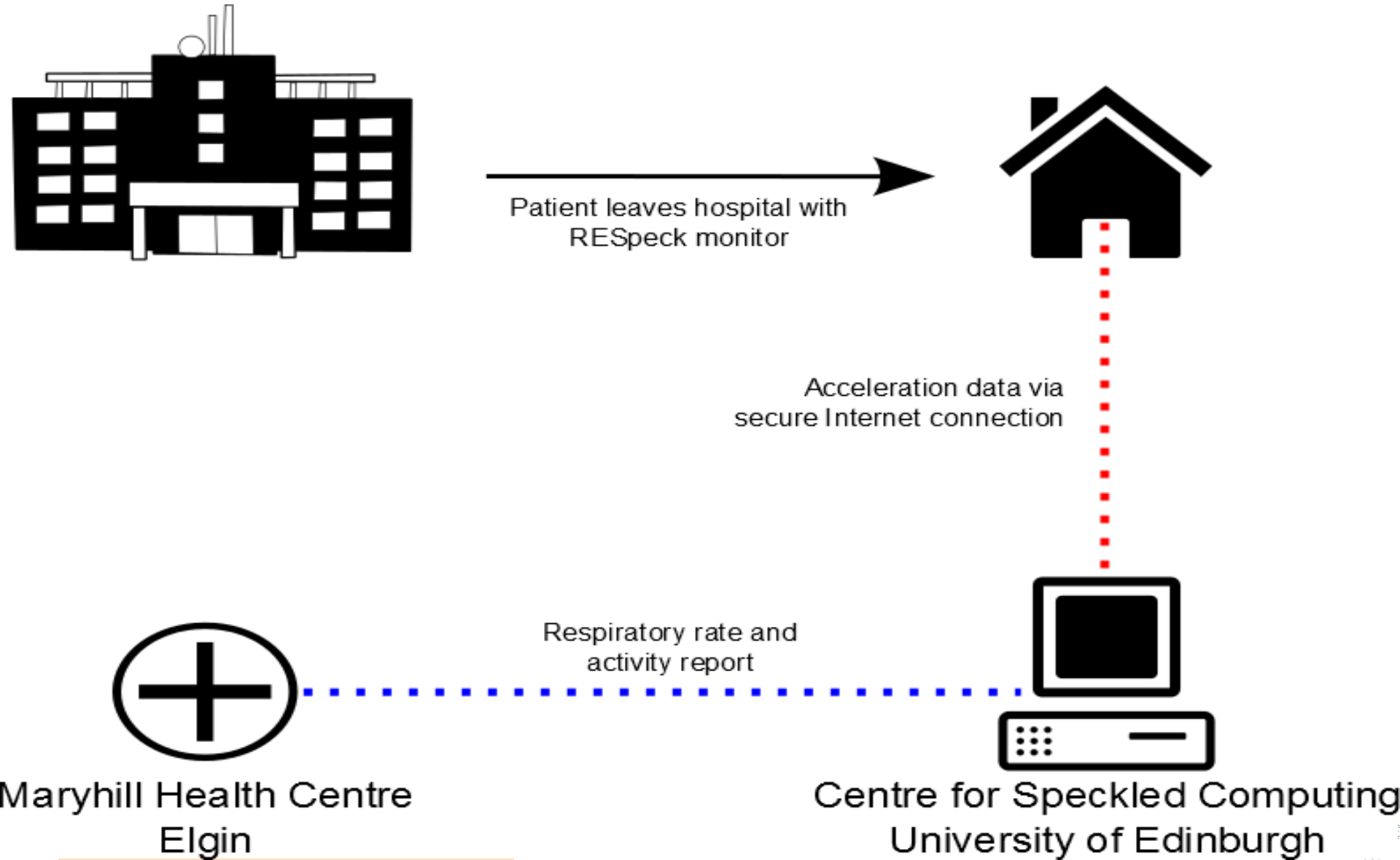
6611

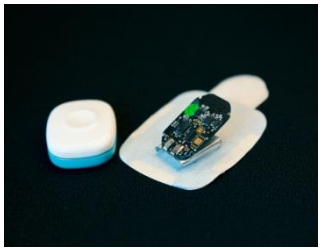
- vote -

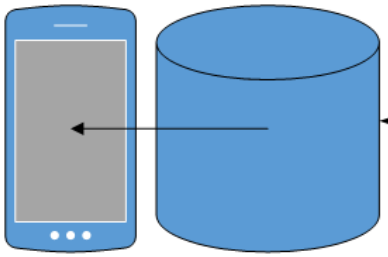

Tain
Lossiemouth
Elgin
Buckie
Macduff
Fraserburgh
Dingwall
Nairn
Forres
Keith
Turriff
Mintlaw
Inverness
Huntly
Peterhead
Ellon
Grantown-on-Spey
Inverurie
Aviemore
Cairngorms National Park
Kemnay
Bridge of Don
Aberdeen
Westhill
Peterculter
Braemar
Banchory
Stonehaven

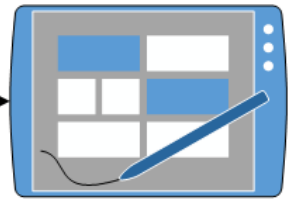

Lossiemouth
Burghead
Buckie
Findhorn
A
Elgin
A96
Kinloss
A941
A96
Fochabers
Forres
A96
A941
A96
Keith
A95
Rothes
A941
Craigellachie

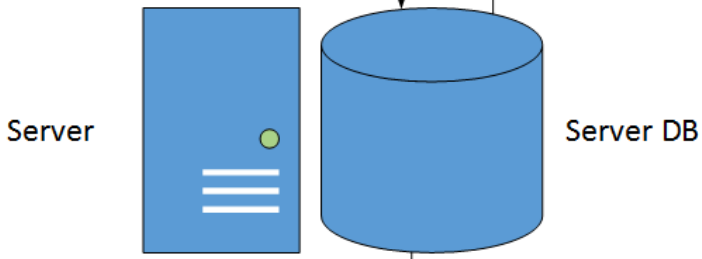
Home Monitoring Data Flow

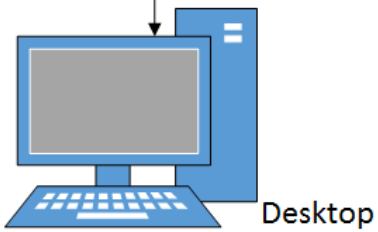


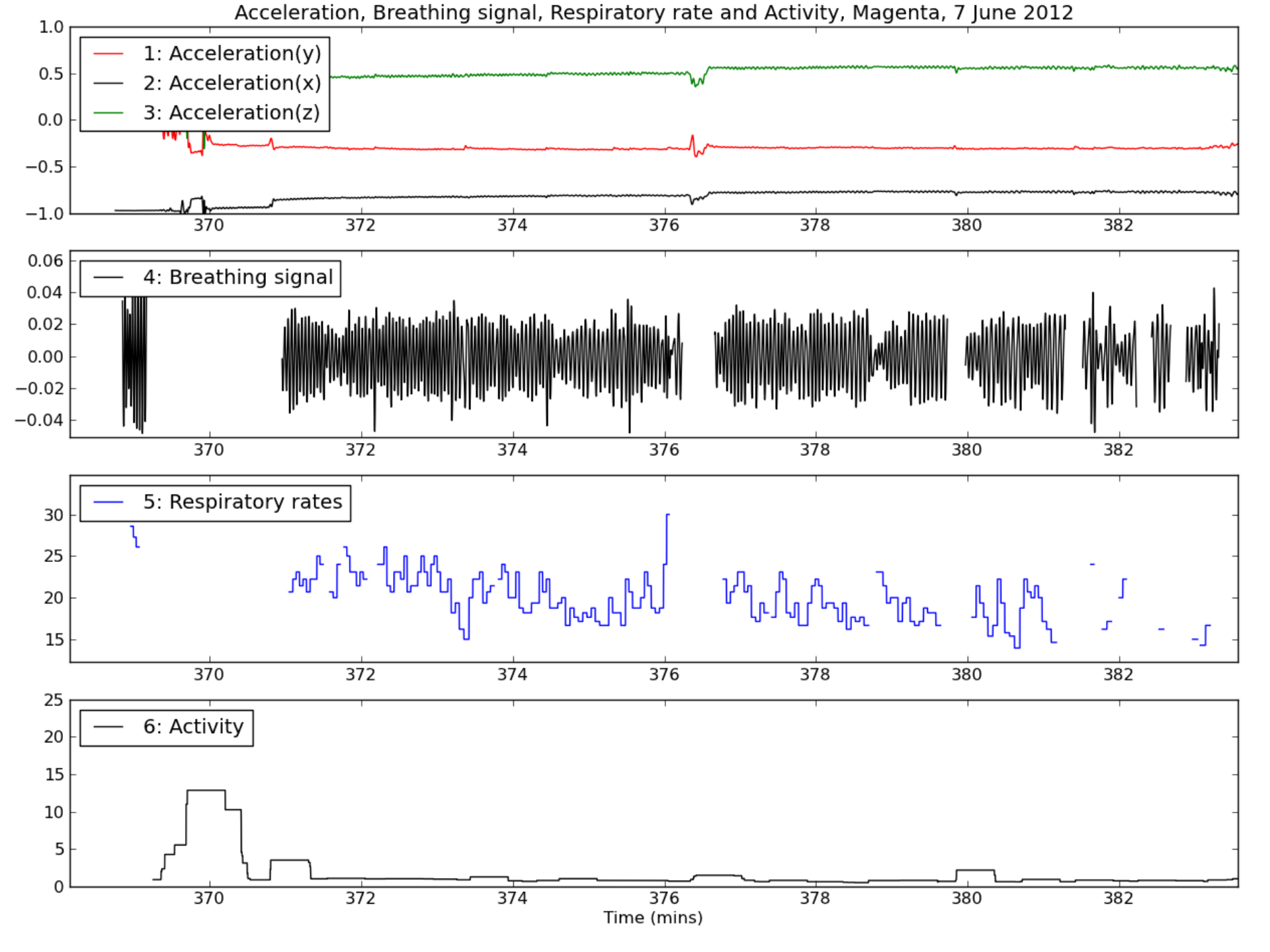


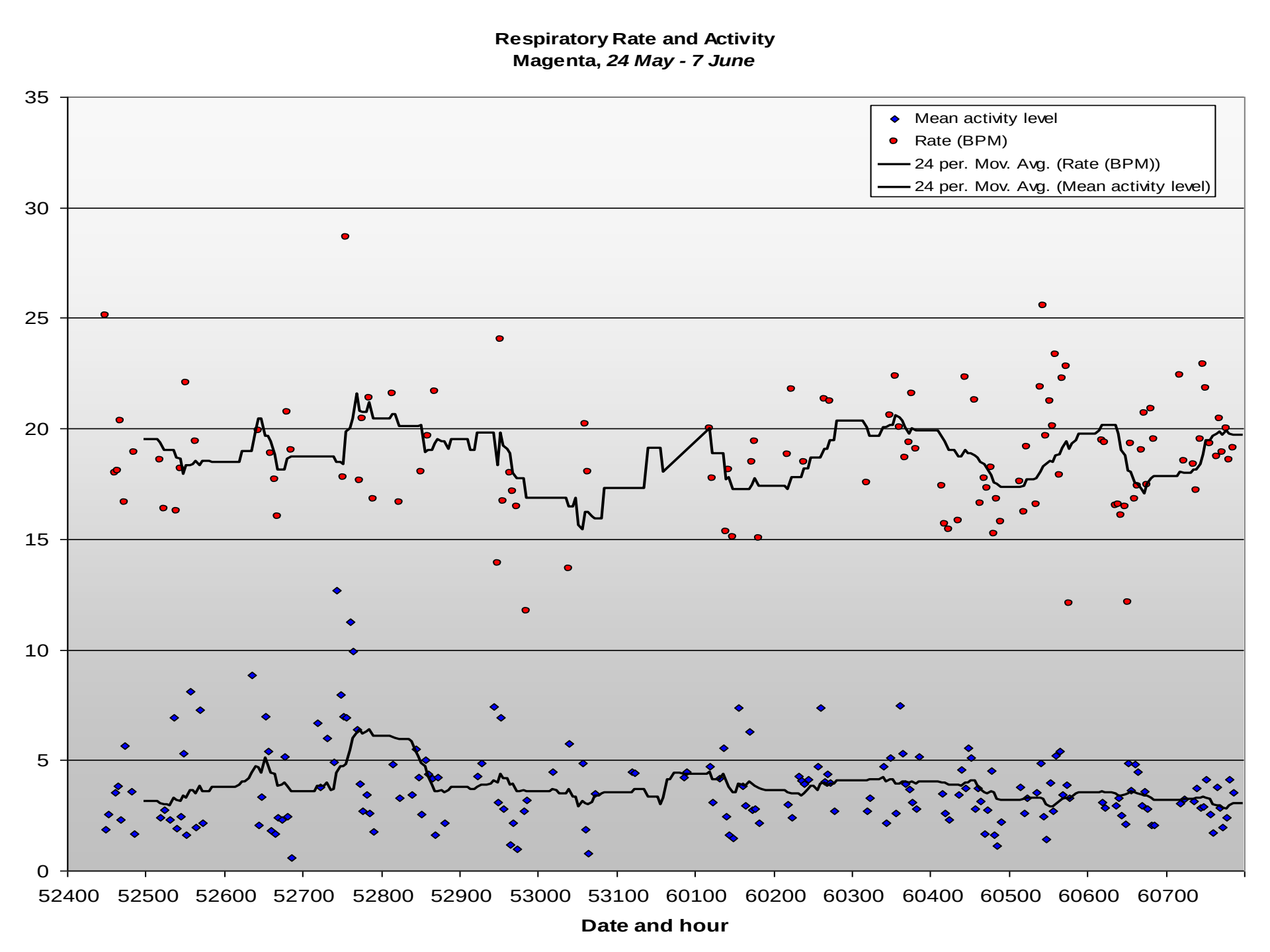

iPhone
SQLite DB

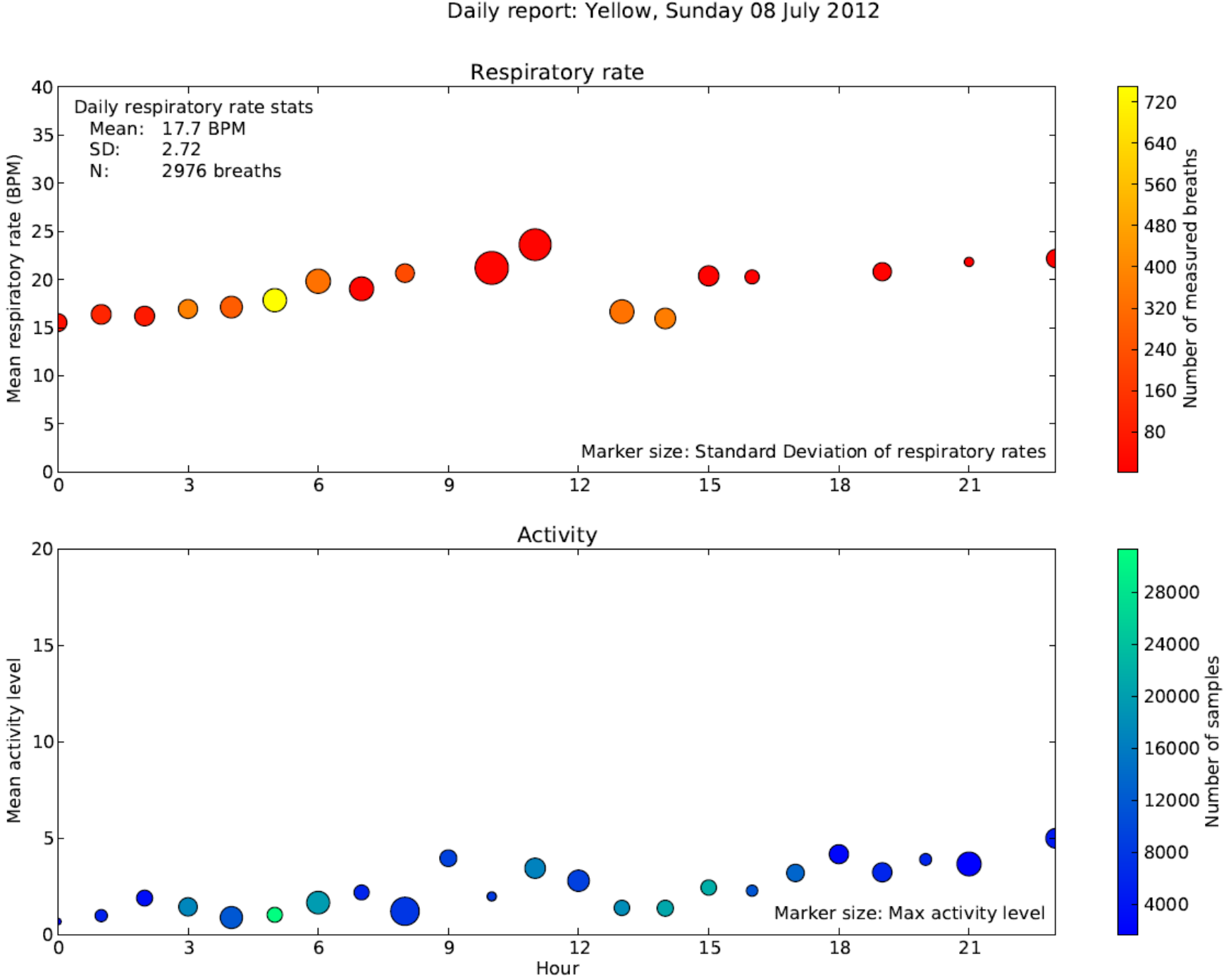

iPad


Server
Server DB


Desktop


Acceleration, Breathing signal, Respiratory rate and Activity, Magenta, 7 June 2012
1: Acceleration(y)
2: Acceleration(x)
3: Acceleration(z)
4: Breathing signal
5: Respiratory rates
6: Activity
Time (mins)


Respiratory Rate and Activity
Magenta, 24 May - 7 June
Mean activity level
Rate (BPM)
24 per. Mov. Avg. (Rate (BPM))
24 per. Mov. Avg. (Mean activity level)
35
30
25
20
15
10
5
0
52400
52500
52600
52700
52800
52900
53000
53100
60100
60200
60300
60400
60500
60600
60700
Date and hour


Daily report: Yellow, Sunday 08 July 2012
Respiratory rate
Daily respiratory rate stats
Mean: 17.7 BPM
SD: 2.72
N: 2976 breaths
Mean respiratory rate (BPM)
Marker size: Standard Deviation of respiratory rates
Number of measured breaths
Activity
Mean activity level
Marker size: Max activity level
Number of samples
Hour

Case Study: Home-based Pulmonary Rehabilitation

Category : Utilitarian

Requirements: Continuous monitoring, Wearable – part of a plaster attached to the chest, unobtrusive, automatic download of data, no recharging – 6 mo battery life, no on-off switch

Users: Patients, GP, Nurses, Hospital consultants

Sensors: 3-D Accelerometer at 12.5 Hz

Actuators: Visual display on tablet/smart phone

Data Analysis: Calculate respiratory rate from sensor data which can vary between 8 to 50 breaths/minute. Present trends in changes in RR after exercises.

Wireless protocol: Bluetooth LE to tablet/phone, WLAN to server

Pulmonary Rehab at Home

Speck

Respiratory Monitor

Exercise Training

Diary

15

Breathing Rate
(BrPM)

Wednesday
15 July 2015
13:25:04

Connected

Speck

Wednesday, 15 July 2015
13:25:33

1/10 Sit to stand

Respiratory Monitor

Exercise Training

Diary

10

Connected

Speck

Wednesday, 15 July 2015
13:25:58

1/10 Sit to stand

Respiratory Monitor

Exercise Training

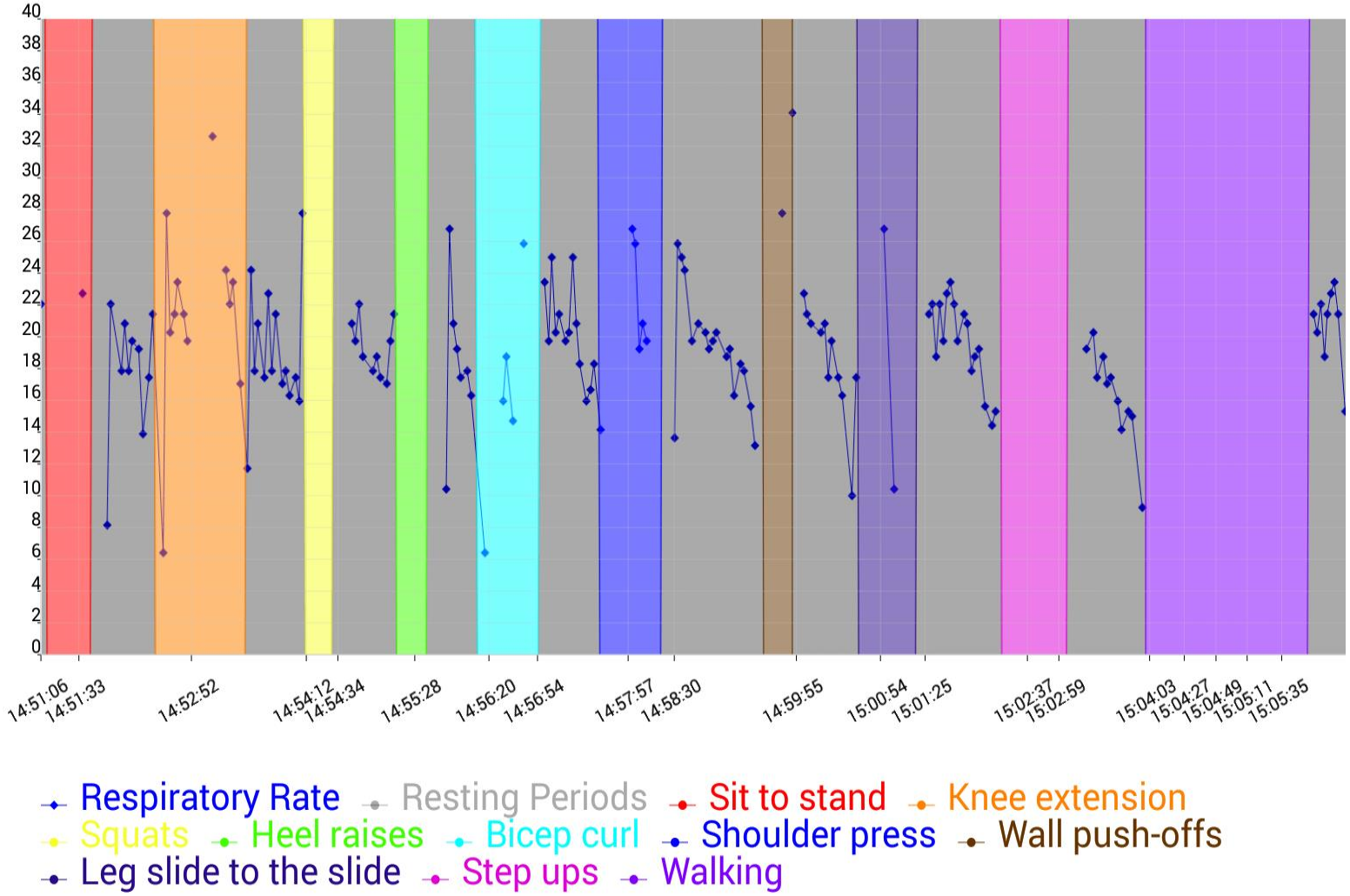
Diary

Rest.

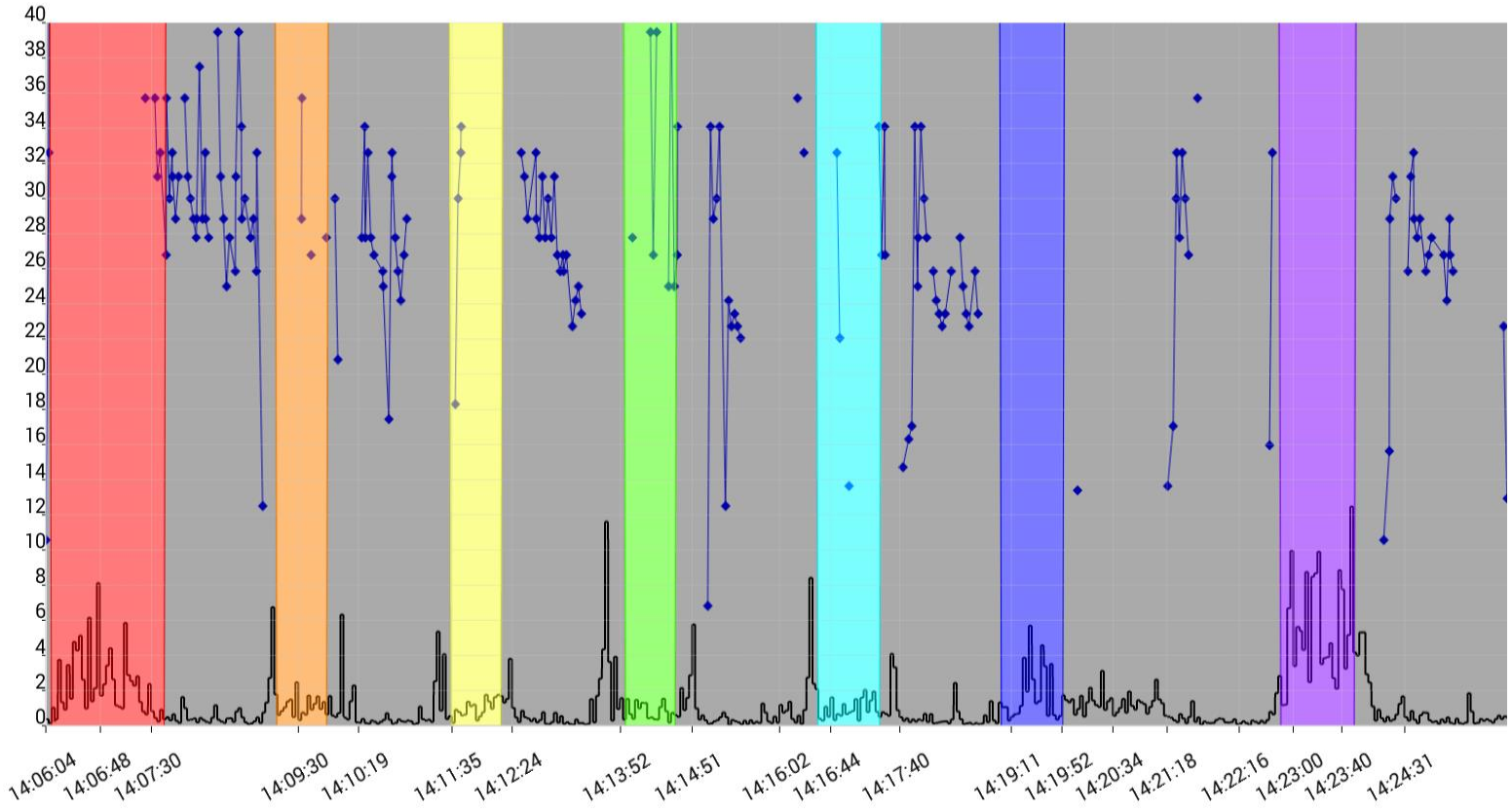
Next: Knee extension

Connected

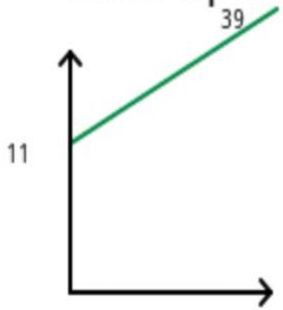
Quiet restful breathing between exercises



Breathing rates with activity data



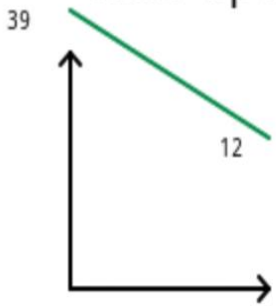
Step-ups
BR before: 11 bpm
BR after: 39 bpm
Time spent: 93 s



Start:[14:6:56]

End: [14:19:45]

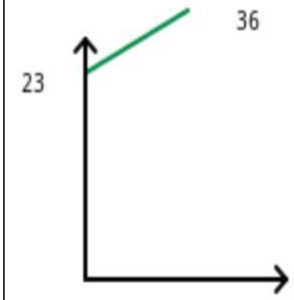
Resting
BR at Start: 39 bpm
BR at End: 12 bpm
Time spent: 90 s



Start:[14:6:56]

End: [14:19:45]

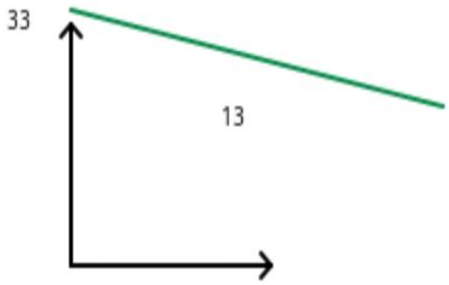
Upward row
BR before: 23 bpm
BR after: 36 bpm
Time spent: 41 s



Start:[14:6:56]

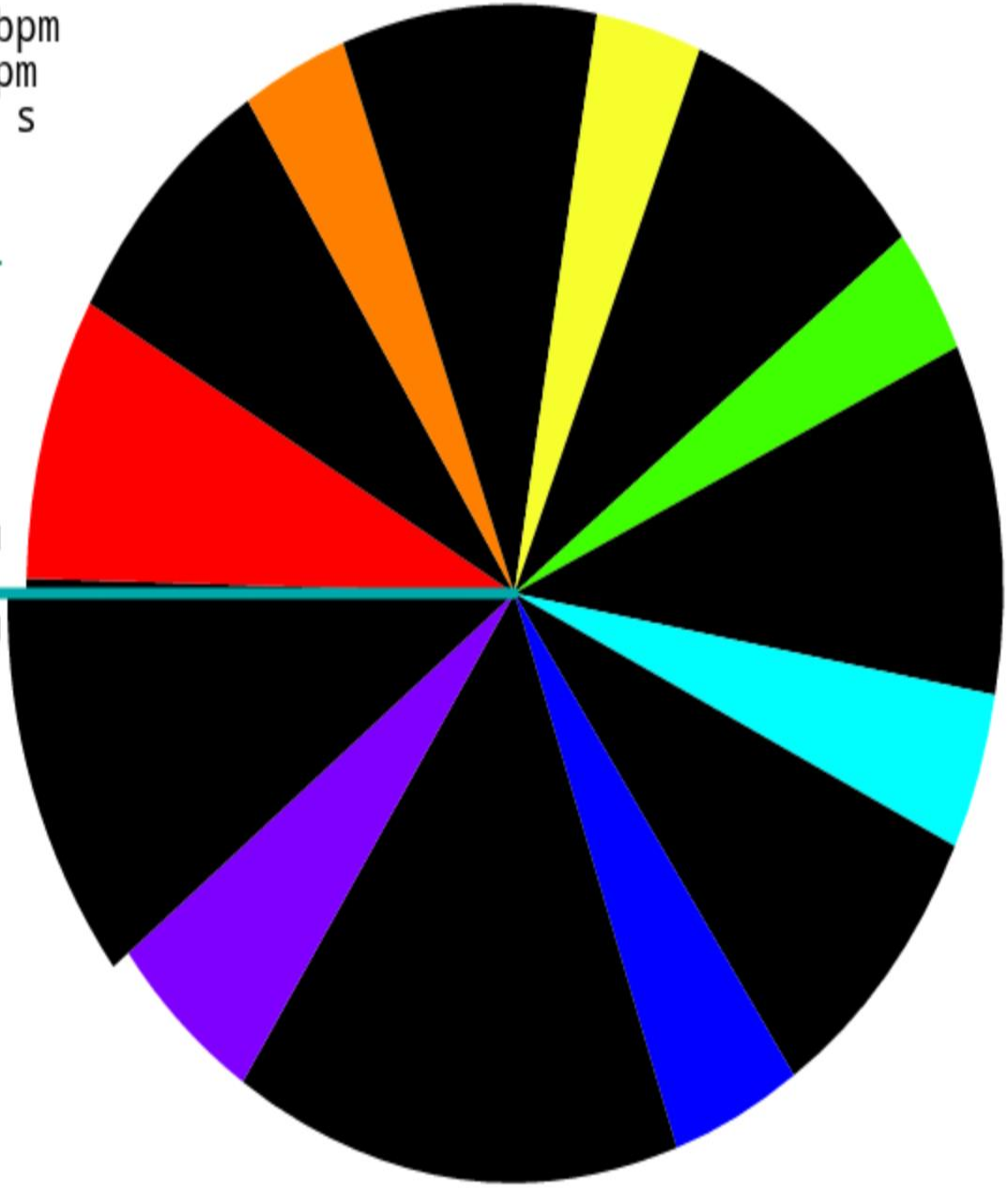
End: [14:19:45]

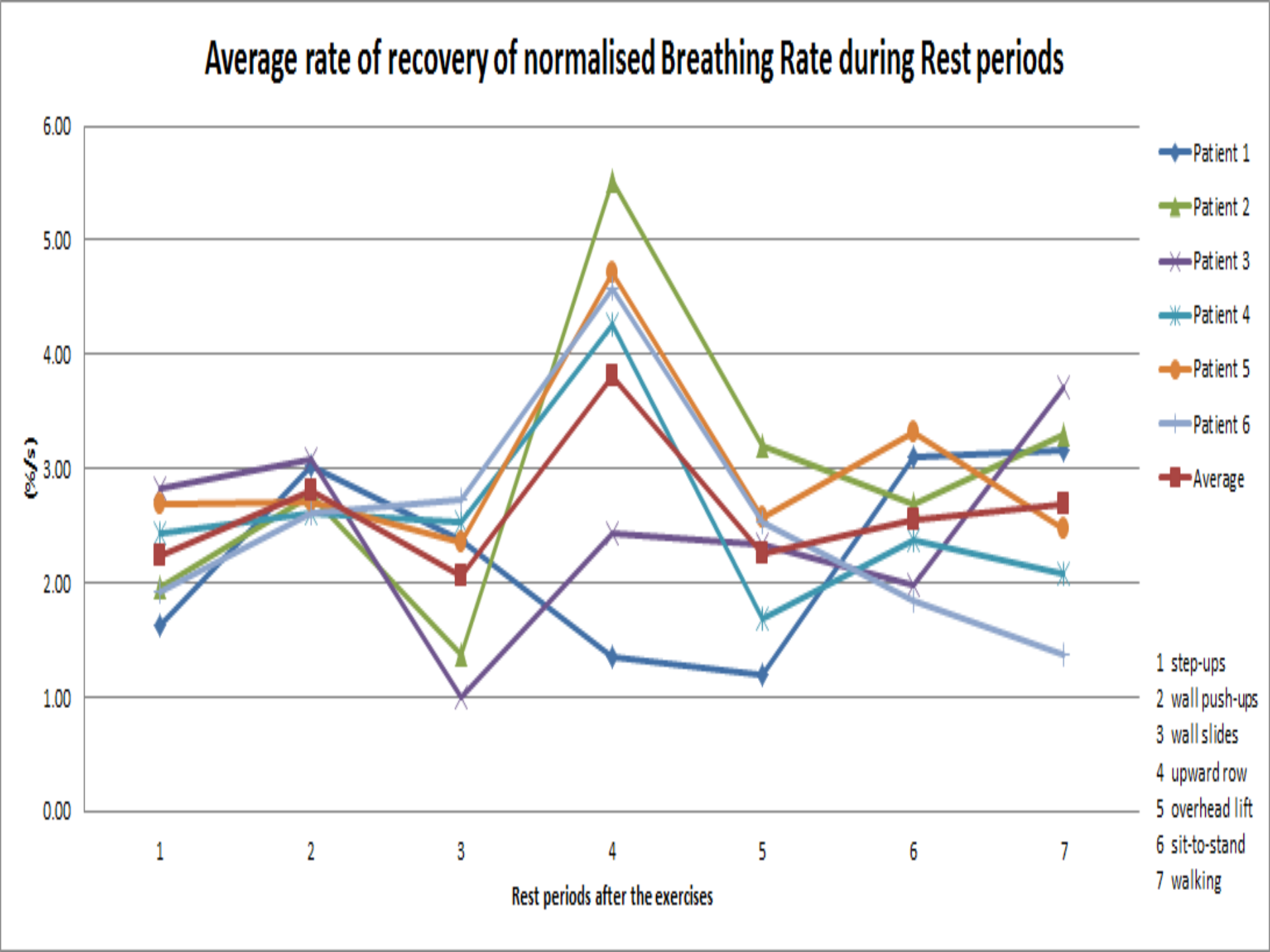
Resting
BR at Start: 33 bpm
BR at End: 13 bpm
Time spent: 176 s

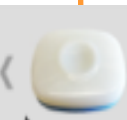


Start:[14:6:56]

End: [14:19:45]




Average rate of recovery of normalised Breathing Rate during Rest periods
6.00
5.00
4.00
3.00
2.00
1.00
0.00
(%/s)
1
2
3
4
5
6
7
Rest periods after the exercises
Patient 1
Patient 2
Patient 3
Patient 4
Patient 5
Patient 6
Average
1 step-ups
2 wall push-ups
3 wall slides
4 upward row
5 overhead lift
6 sit-to-stand
7 walking



Training Results

SUMMARY

15	28	5	12
Average Breathing Rate (BrPM)	Maximum breathing rate (BrPM)	Minimum Breathing Rate (BrPM)	Average Variation in Breathing Rate (BrPM)

2015
Week 31

Previous Week | Next Week

ID	Monday 27 Jul				Tuesday 28 Jul				Wednesday 29 Jul				Thursday 30 Jul				Friday 31 Jul				Saturday 01 Aug				Sunday 02 Aug			
	Ref. BrPM (R)	Max BrPM (E)	Min BrPM (E)	Var BrPM (E)	Ref. BrPM (R)	Max BrPM (E)	Min BrPM (E)	Var BrPM (E)	Ref. BrPM (R)	Max BrPM (E)	Min BrPM (E)	Var BrPM (E)	Ref. BrPM (R)	Max BrPM (E)	Min BrPM (E)	Var BrPM (E)	Ref. BrPM (R)	Max BrPM (E)	Min BrPM (E)	Var BrPM (E)	Ref. BrPM (R)	Max BrPM (E)	Min BrPM (E)	Var BrPM (E)	Ref. BrPM (R)	Max BrPM (E)	Min BrPM (E)	Var BrPM (E)
4001	16	42	4	4	9	:	:	:																				
4002					13	31	3	4									14	27	5	5								
4003	16	47	4	6					22	38	5	7																
4005																	:	:	:	:								
4006					6	36	11	2	15	38	9	2	12	28	14	3					12	24	5	4				
4014									:	33	7	1									:	:	:	:	24	36	4	6

Notes:

BrPM - Breaths Per Minute.

Ref. BrPM - The 'Reference Breathing Rate' is the average quiet breathing rate at rest before the start of the exercises.

Var. BrPM - This refers to the average variation of the breathing rate during the rest periods following the exercises.

The Max and Min refer to the maximum and minimum breathing rates during the rest periods following the exercises over the entire session.

Patient Id: 4002
Friday 31 July 2015

Start: 11:58 Duration: 32 minutes

Exercise	Max	Min	Mean	Std. Dev.
Sit to Stand	23	6	17	5
Knee Extension	26	9	18	4
Squats	24	5	18	4
Heel Raises	21	10	17	4
Bicep Curl	25	7	15	4
Shoulder Press	27	6	14	7
Wall Push Offs	22	8	16	4
Leg Slide (to the side)	23	6	17	6
Step Ups	21	5	12	5
Walking	21	5	18	5

Notes:

The breathing rate (BrPM) is calculated during the rest period immediately following an exercise.

The Max and Min values are calculated as the averages of the five highest and five lowest values, respectively, during the rest period following an exercise.

Notes:

The breathing rate (BrPM) is calculated during the rest period immediately following an exercise.

The Max and Min values are calculated as the averages of the five highest and five lowest values, respectively, during the rest period following an exercise.

Notes

Date/Time	Note

New note

Add note

Patient Id: 4006
Thursday 13 August 2015

Start: 12:03 Duration: 23 minutes

Exercise	Max.	Min	Mean	Std. Dev.
Sit to Stand	-	-	-	-
Knee Extension	23	13	19	5
Squats	33	33	33	0
Heel Raises	38	38	38	0
Bicep Curl	22	17	18	2
Shoulder Press	18	17	17	0
Wall Push Offs	18	18	18	0
Leg Slide (to the side)	-	-	-	-
Step Ups	21	21	21	0
Walking	16	8	13	3

Notes:
The breathing rate (BrPM) is calculated during the rest period immediately following an exercise.
The Max and Min values are calculated as the averages of the five highest and five lowest values, respectively, during the rest period following an exercise.

Diary entry at 12:27

Question	Answer
I am breathless at night: (Borg Score)	0
I can climb this many steps without stopping:	20
I can walk this far without having to stop:	20 mins
What makes my breathing worse:	Smoking or being around smoke
I cough up this much sputum (tsp):	0
My normal appetite is normally:	Very Good

Notes

Date/Time	Note

New note

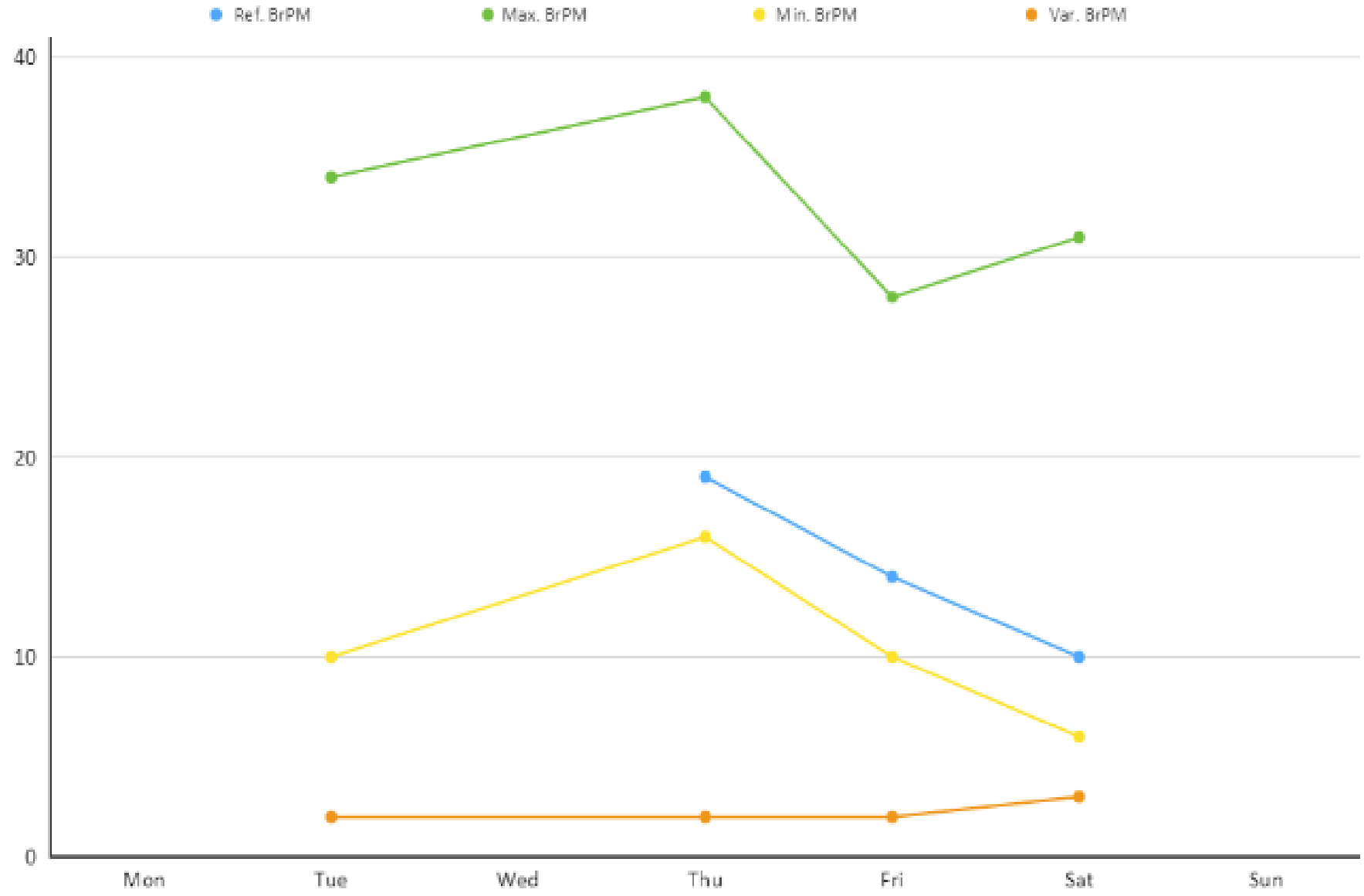
Add note

Diary entry at 12:27

Question	Answer
I am breathless at night (Borg Score)	0
I can climb this many steps without stopping	20
I can walk this far without having to stop	20 mins
What makes my breathing worse	Smoking or being around smoke
I cough up this much sputum (tsp)	0
My normal appetite is normally	Very Good

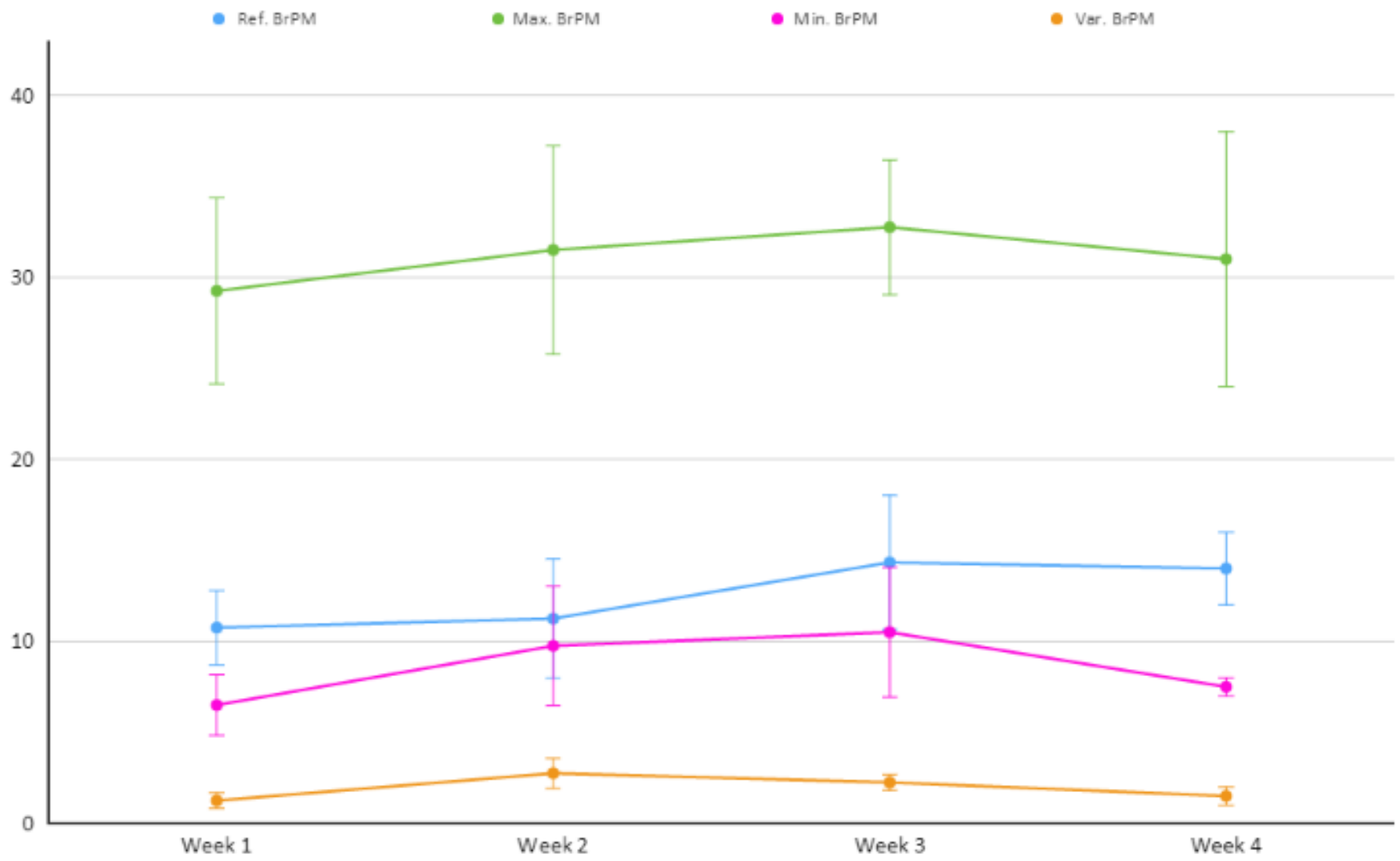
Notes

Date/Time	Note

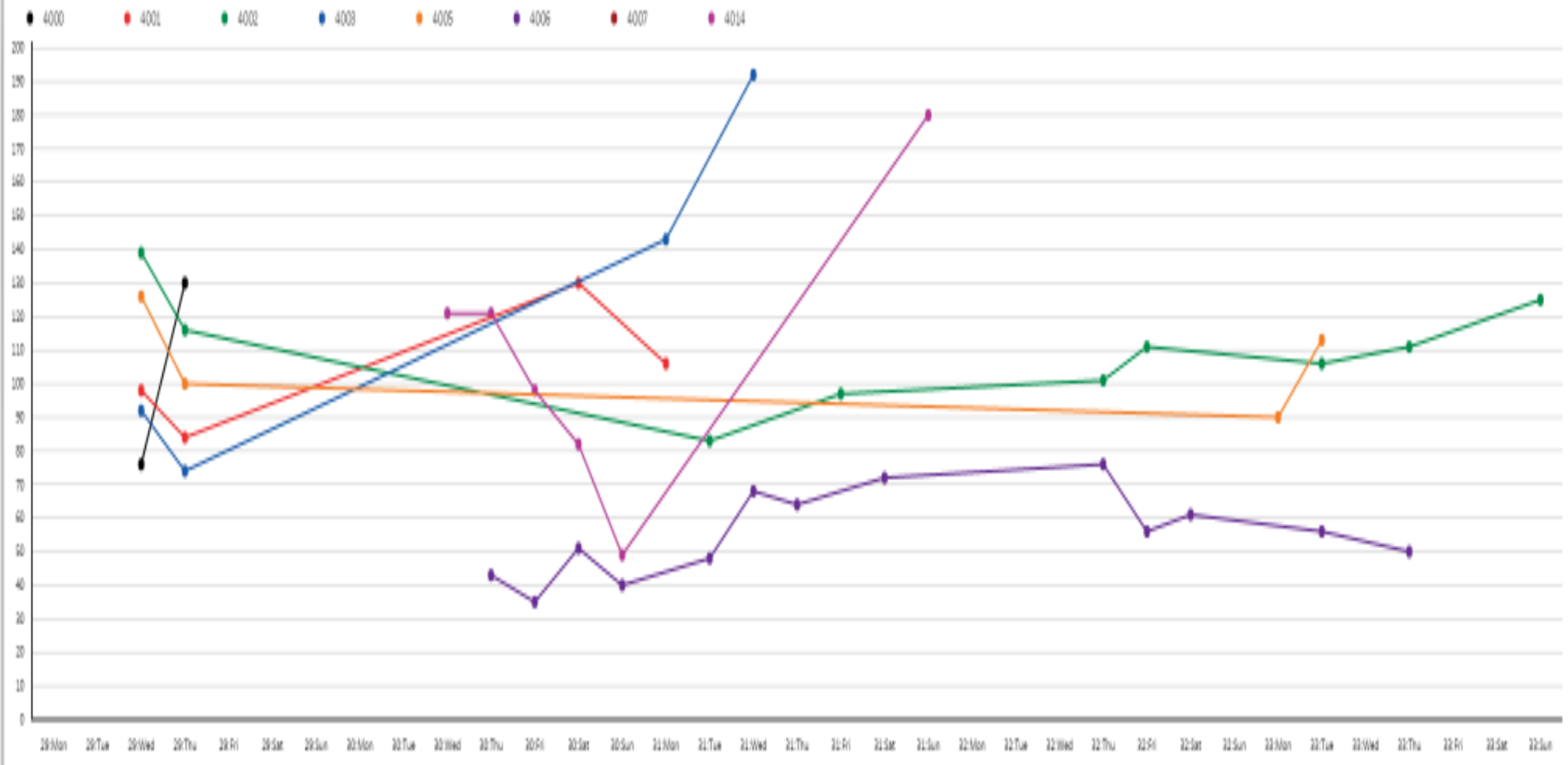


4-weekly view

Patient Id: 4006
Week 30 - Week 33 (20 Jul - 16 Aug)



ID	28.Mon	28.Tue	28.Wed	28.Thu	28.Fri	28.Sat	28.Sun	30.Mon	30.Tue	30.Wed	30.Thu	30.Fri	30.Sat	30.Sun	31.Mon	31.Tue	31.Wed	31.Thu	31.Fri	31.Sat	31.Sun	32.Mon	32.Tue	32.Wed	32.Thu	32.Fri	32.Sat	32.Sun	33.Mon	33.Tue	33.Wed	33.Thu	33.Fri	33.Sat	33.Sun
4000	N.A.	N.A.	78	130	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
4001	N.A.	N.A.	98	84	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	130	N.A.	108	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
4002	N.A.	N.A.	139	116	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	83	N.A.	N.A.	97	N.A.	N.A.	N.A.	N.A.	N.A.	101	111	N.A.	N.A.	N.A.	108	N.A.	111	N.A.	N.A.	125
4003	N.A.	N.A.	92	74	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	143	N.A.	192	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
4005	N.A.	N.A.	128	100	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	90	113	N.A.	N.A.	N.A.	N.A.	N.A.
4006	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	43	35	51	40	N.A.	48	68	64	N.A.	72	N.A.	N.A.	N.A.	N.A.	78	58	61	N.A.	N.A.	58	N.A.	50	N.A.	N.A.	N.A.
4007	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
4014	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	121	121	98	82	49	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	180	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.



Conclusions

- Wearable device + Mobile App
- Patients perform Pulmonary rehab in their homes
- Respiratory and activity monitoring data
- Conformance and validation of exercises
- Monitoring any change in conditions of patients