Pulse Oximetry and CRSS – What is normal?

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Acknowledgements

- Sam Spaven
- Sleep physiology team Southampton
    - Jo Gavlak
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    - Michelle Davies
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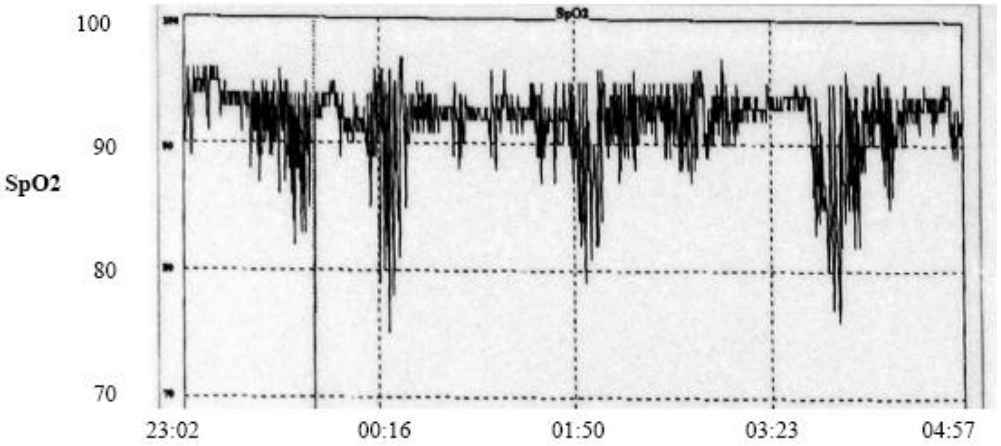
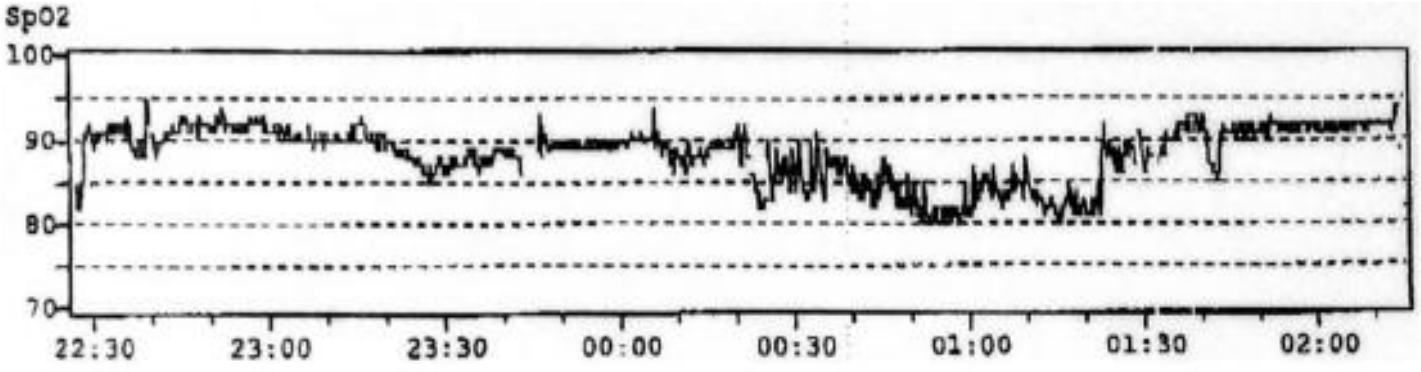
    - Steve Frampton
    - Hasnaa Ismail Koch
    - Andrea Burgess
- Cathy Hill

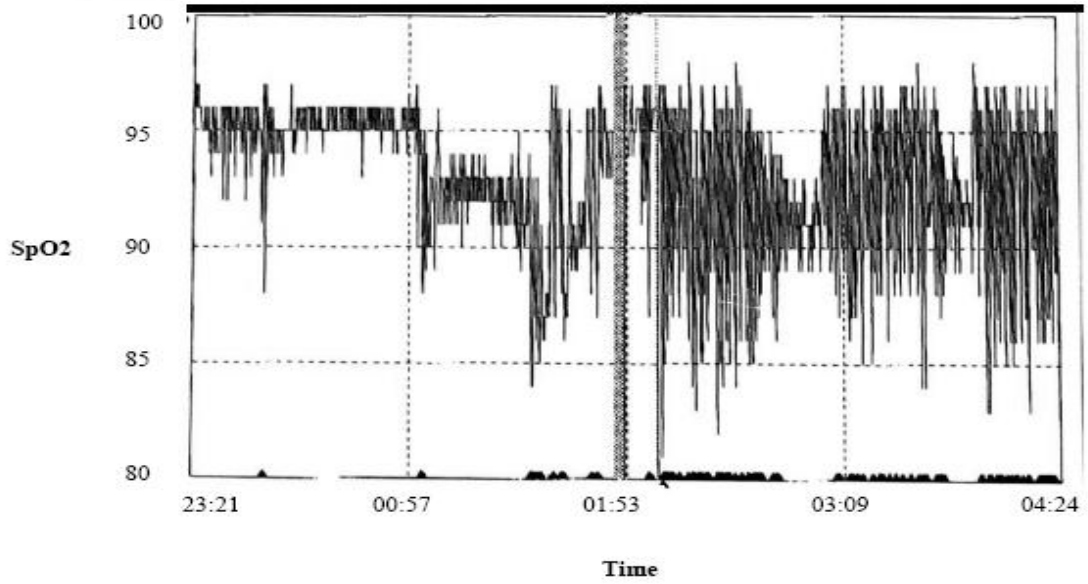
"I don't have any strong basis for interpreting them other than trying to fumble through it with a little common sense"



Study 1

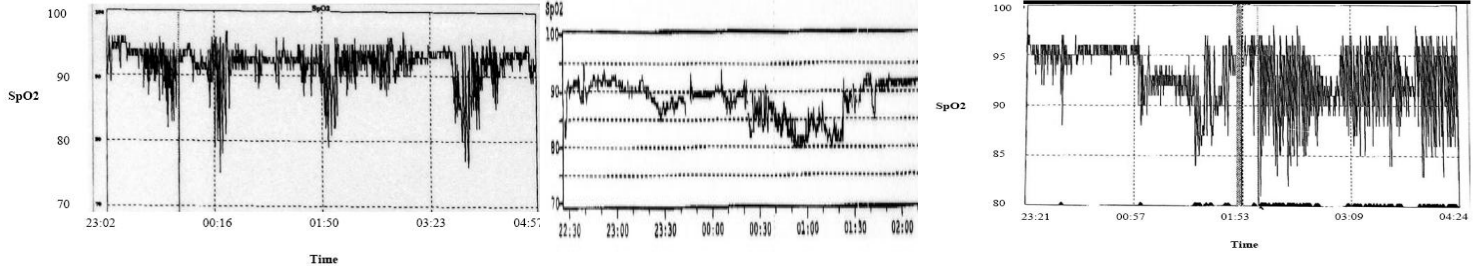


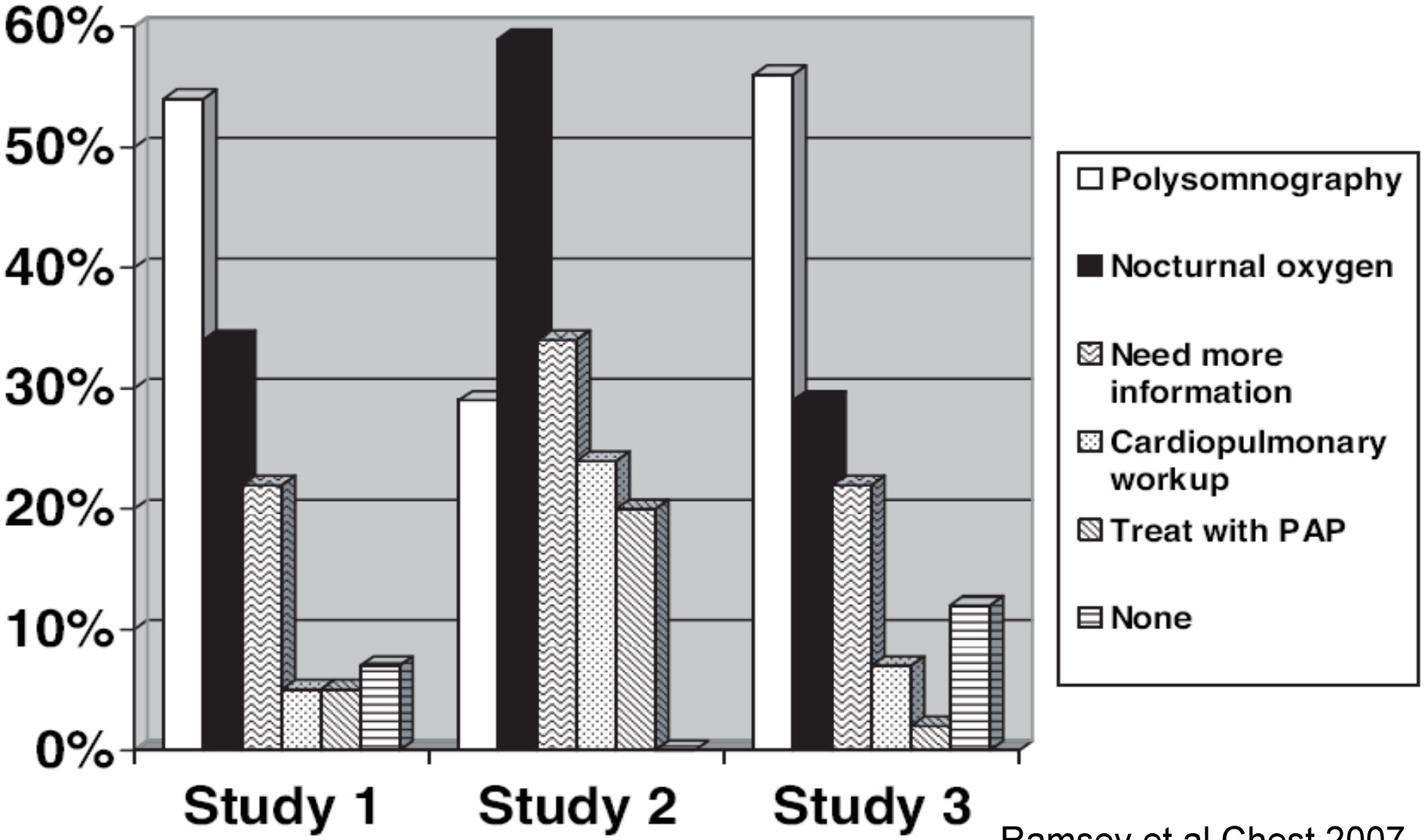
Study 2



Study 3

SOUTHAMPTON
Children's Hospital

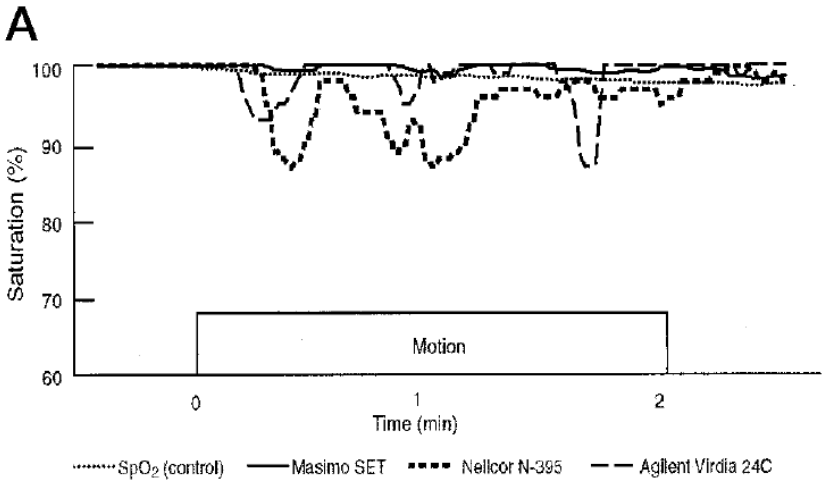




Ramsey et al Chest 2007

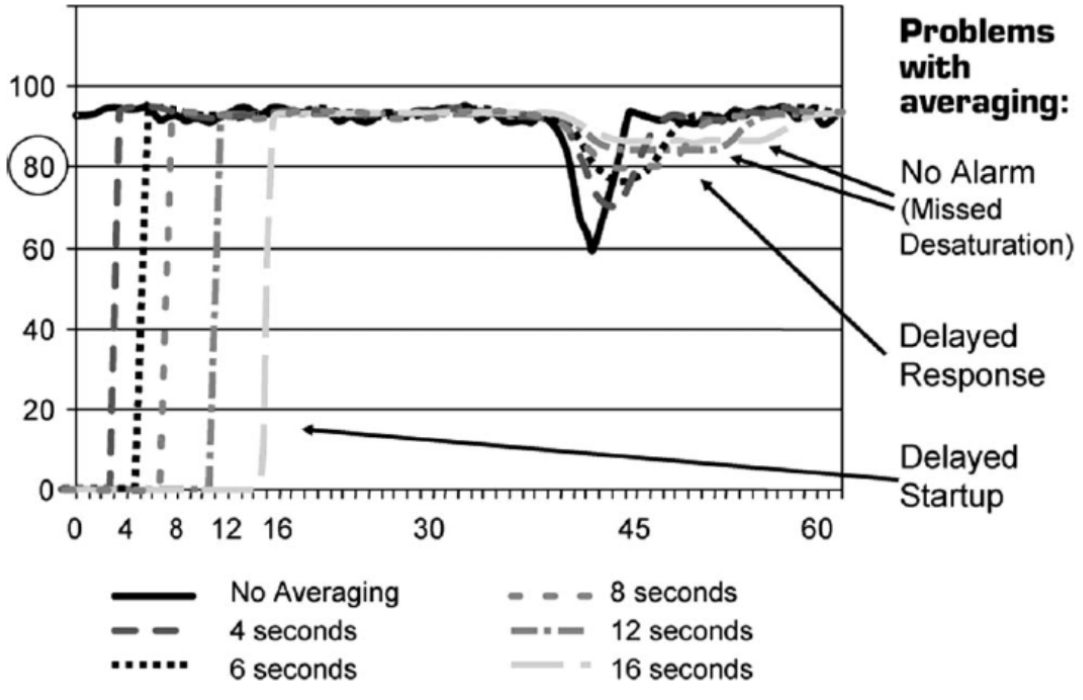
Overview

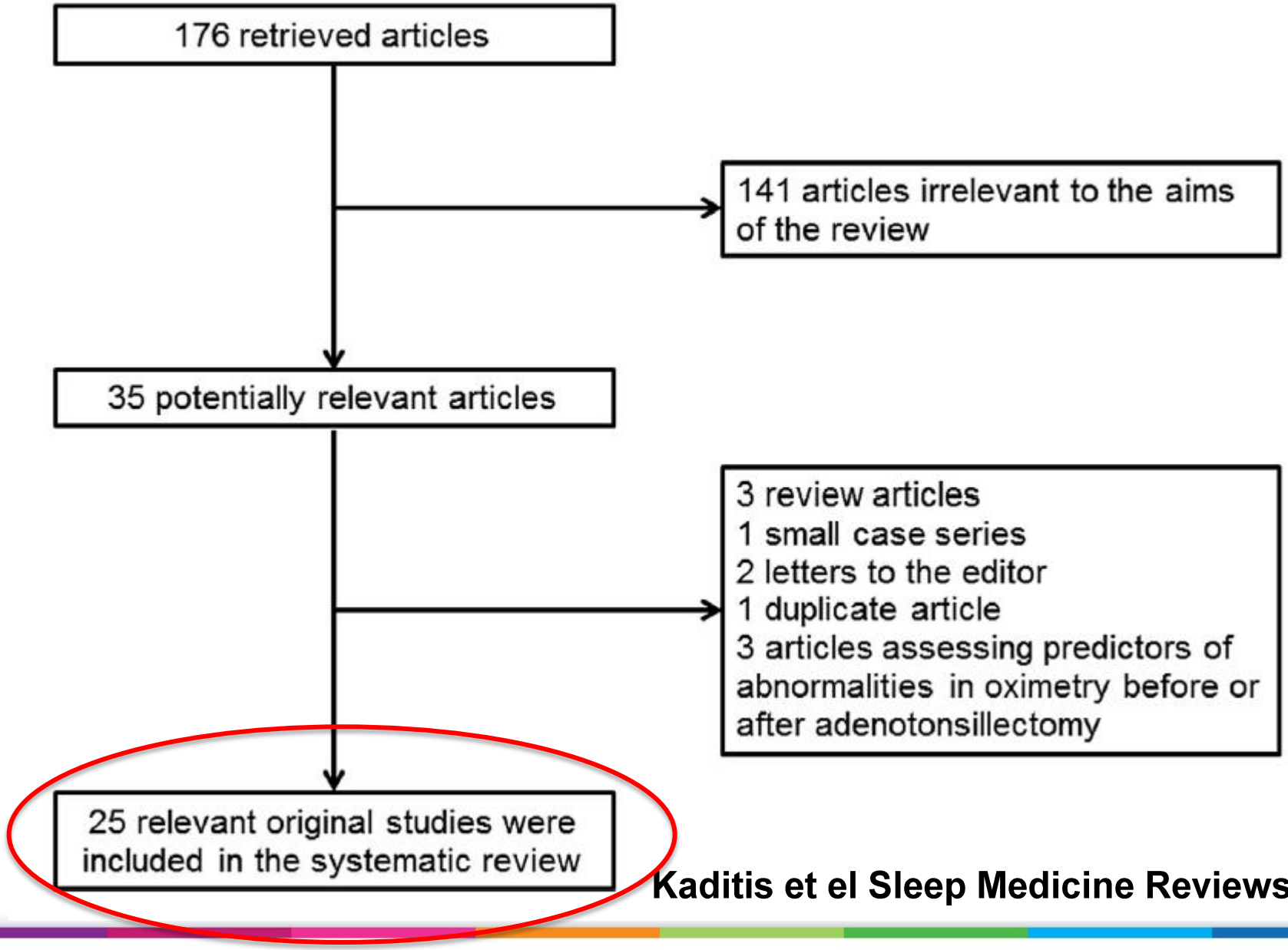
- What do we know about normal values in oximetry and CRSS?
  - What parameters should we use to define abnormality and what should our cut off be
- The balance between oximetry and CRSS
- What are the unknowns
- Healthy discussion



Effect of motion artefact

Effect of averaging times





Kaditis et el Sleep Medicine Reviews 2015

Author, year (reference number)	Type of study	Quality of evidence	Subjects-Methods	Nocturnal oximetry indices and definitions	Reference values
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Uliel et al., *2004* [24]	Cross-sectional study	IV	70 healthy children and adolescents (1–15 y.o.) without risk factors for SDB underwent polysomnography.	Baseline SpO_2; SpO_2 nadir	Mean baseline SpO_2 was 97.2 ± 0.85%; mean SpO_2 nadir was 94.6 ± 2.2%.
Traeger N et al. *2005* [23]	Retrospective cross-sectional analysis of a prospective cohort study	IV	66 children (2.5–9.4 y.o.) with normal growth and development who underwent polysomnography.	Baseline SpO_2; SpO_2 nadir	Mean baseline SpO_2 was 97 ± 1%; mean SpO_2 nadir was 92 ± 3%.
Saito et al. *2007* [22]	Prospective cohort study	III	225 children (1.4–10 y.o.) with symptoms indicative of SDB and 25 healthy control children without symptoms of SDB underwent nocturnal oximetry.	ODI_3: ≥3% drops in SpO_2 per hour of artifact-free recording time; ODI_4: ≥4% drops in SpO_2 per hour of artifact-free recording time; SpO_2 nadir.	Mean ODI_3 in controls was 0.74 ± 0.65 episodes/h; mean ODI_4 was 0.21 ± 0.29; mean SpO_2 nadir was 94.56 ± 2.38%; 33.8% of children with symptoms of SDB had ODI_3 values < mean + 2 standard deviations in controls.
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Abbreviations: BMI: body mass index, 95% CI: 95% confidence interval, ODI_3: oxyhemoglobin desaturation (≥3%) index, ODI_4: oxyhemoglobin desaturation (≥4%) index, OR: odds ratio, OSAS: obstructive sleep apnea syndrome, SDB: sleep-disordered breathing, SpO_2: oxygen saturation of hemoglobin.

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5 second averaging time
25 healthy children

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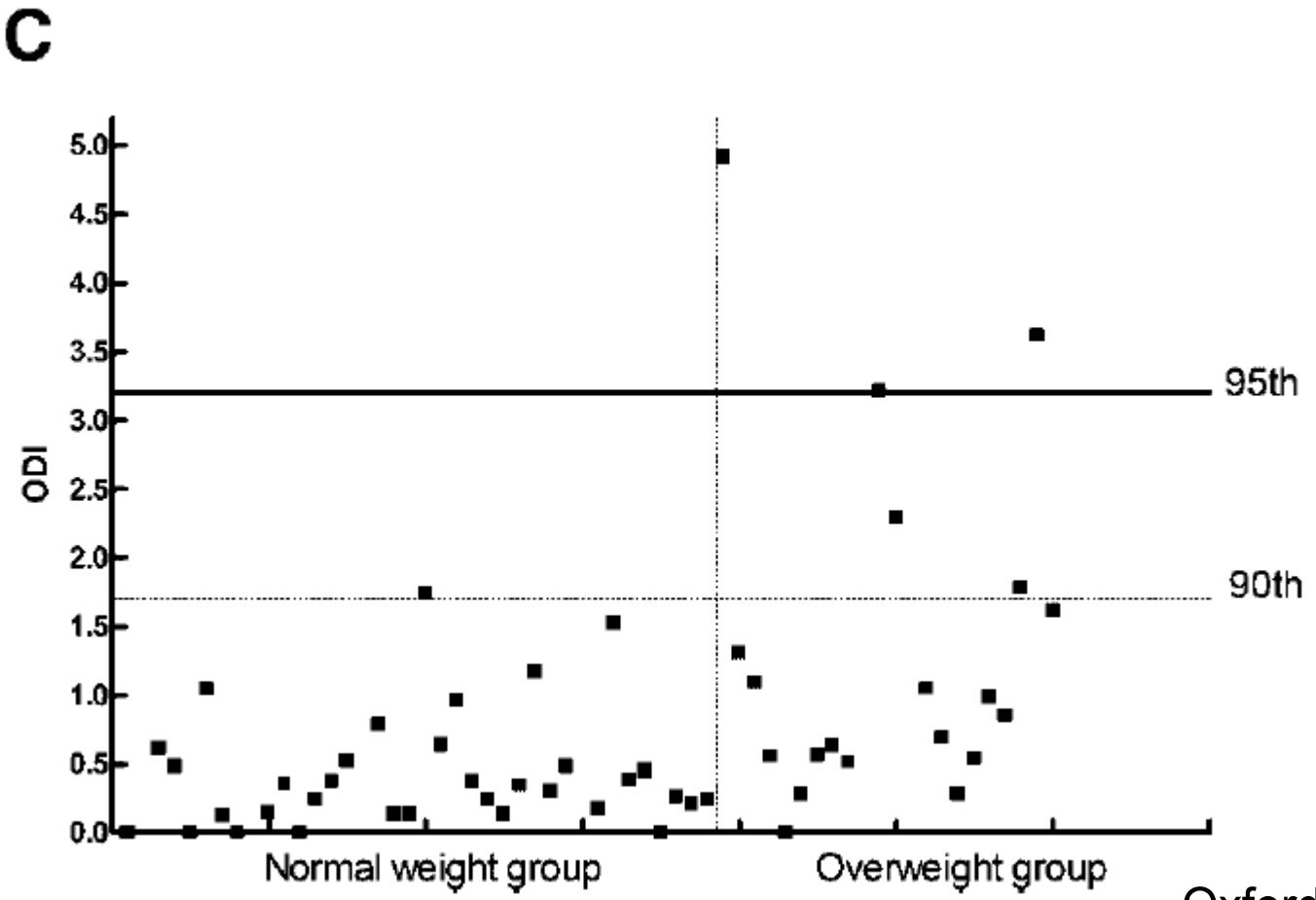
Overall findings healthy children over 1year

- Baseline saturations
  - Mean saturations 97% (range 95-98%
- ODI_4 (Urschitz paper)
  - No resp complaints 2.2
  - Whole cohort 3.9
- Number of desaturations below 90% = 1
- Clusters of desaturations 95th centile = 2

3% versus 4% ODI

3% versus 4% ODI

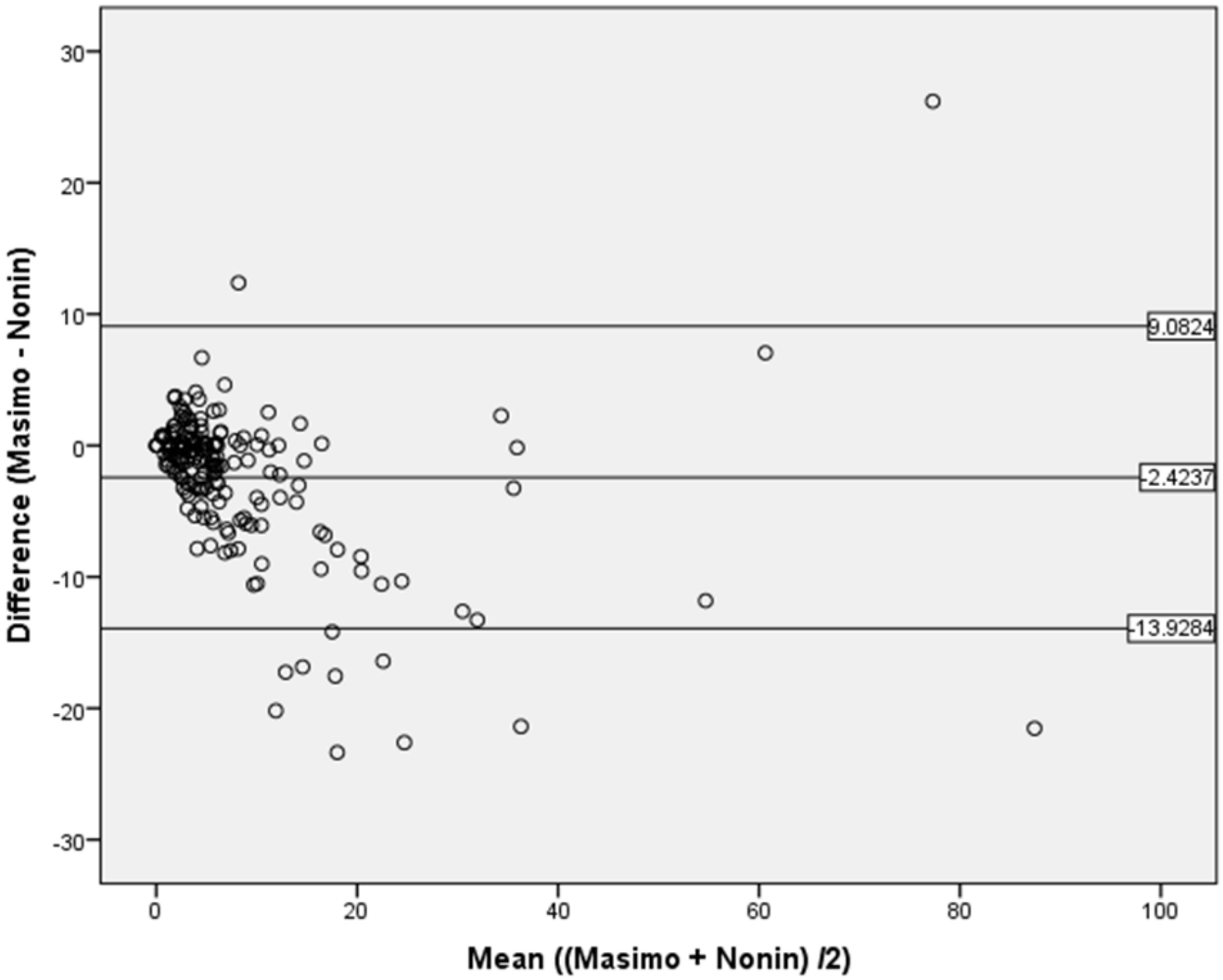


Oxford Medilog
Verhulst et al 2007

Table 2 Data of healthy children and temporarily defined normal range based on mean + 2S.D. or −2S.D.

	Low	ODI4	ODI3	TDD95
Mean	94.56	0.21	0.74	2.08
S.D.	2.38	0.29	0.65	4.91
Temporarily defined normal range	>89	<0.78	<2.04	>11.9

Saito et al
Nellcor (5s averaging)
25 healthy controls
100% improvement in sats if ODI3 >5



N = 184
Age range 1mth – 18 years

Indications for oximetry studies

Indications for oximetry studies

- Weaning children from oxygen
  - Babies with BPD
  - Children discharged in oxygen post infection eg trisomy 21
  - Determine desired FiO_2 pre discharge
- Risk assessment preoperatively for children undergoing T+A
- Screening tool for OSA
  - Desaturation indices, dips below 90% and clusters of desaturation

Where should we define our cut of for normality?

- Which criteria should we use?

Children investigated for OSA Southampton

- Discrete population of children referred for sleep studies
- Exclusion criteria
  - Co-morbidities eg CP, DS, PWS
  - Children <1 year of age

Cut offs for OAHI >2 n=19/75

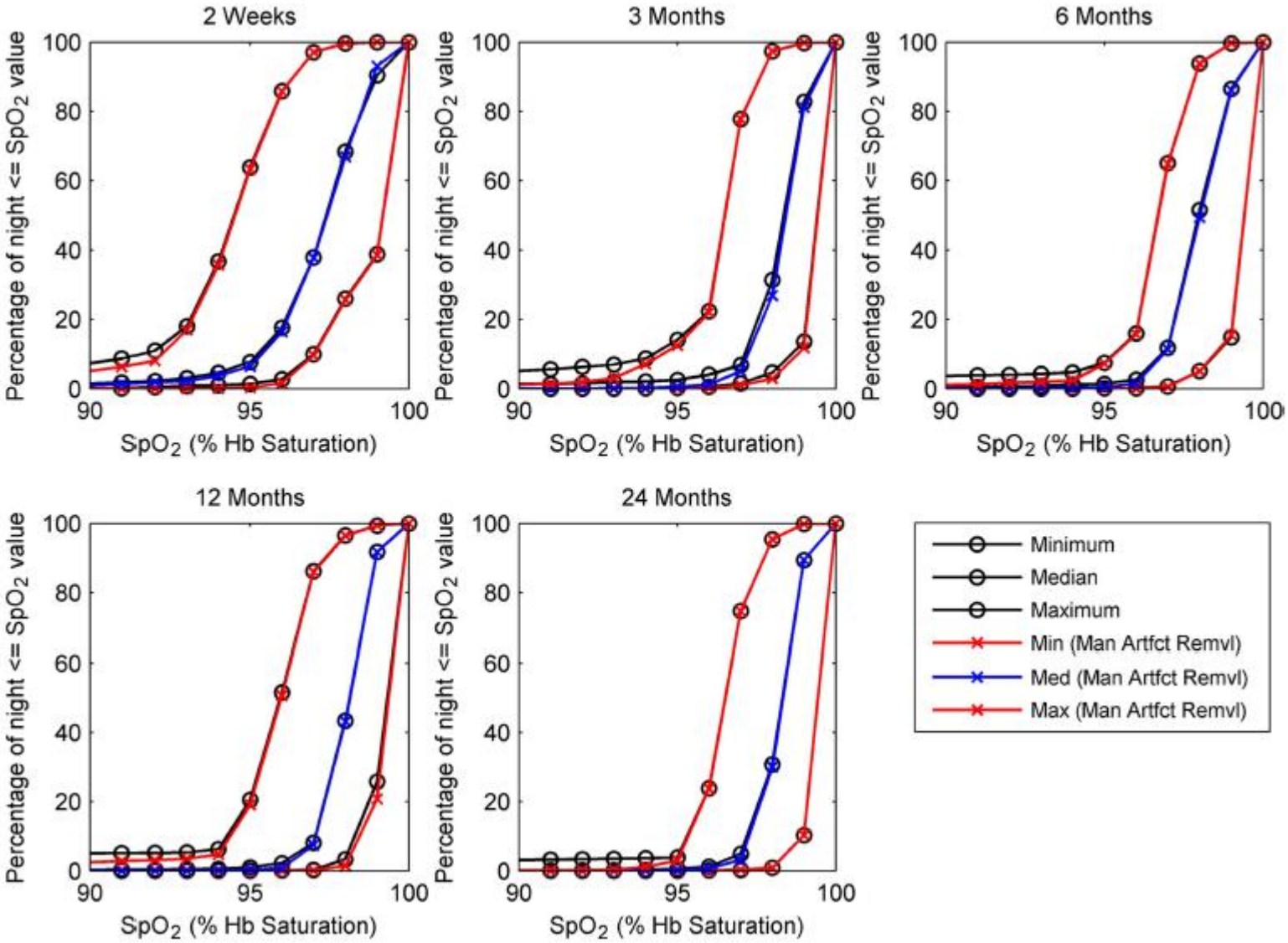
Cut offs for OAHI >2 n=19/75

Cut-offs	Positive predictive value	Sensitivity
McGill >1 (at least 3 clusters of desaturation events + at least 3 desaturations below 90%)	8/9 = 89%	
ODI_4 >3	11/14 = 78%	
ODI_4 >4	10/10 = 100%	53%
ODI_3 >6	10/13 = 77%	
ODI_3 >8	8/8 = 100%	42%
Delta index 12s >0.5	9/14 = 64%	
Delta index 12s >0.6	8/9 = 89%	
Delta index 12s >0.65	4/4 = 100%	21%

What do we know about infants?

	2 weeks	3 months	6 months	12 months	24 months
Mean saturations	97.6 (88-97)	98.5 (97-100)	98.3 (97-100)	98.4 (96-100)	98.7 (97-100)
Median saturations	98.0 (95-100)	99.0 (97-100)	98.0 (97-100)	99.0 (96-100)	99.0 (97-100)
Sat5	95.0 (88-97)	97.0 (90-99)	97.0 (96-99)	97.0 (89-99)	97.5 (96-99)
Sat10	96.0 (92-98)	98.0 (95-99)	97.0 (95-98)	98.0 (96-100)	98.0 (97-100)

Terrill et al ADC 2015

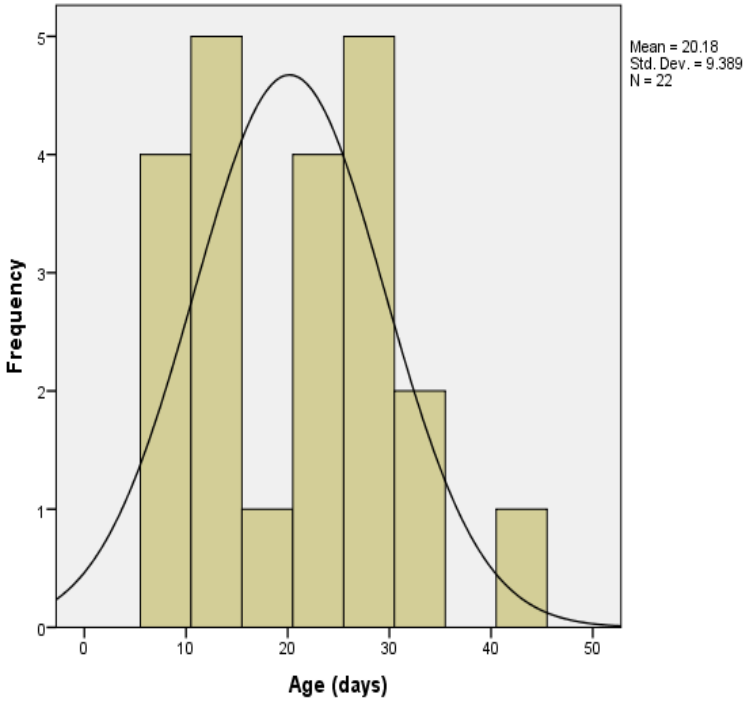

2 Weeks
3 Months
6 Months
12 Months
24 Months
Percentage of night <= SpO2 value
SpO2 (% Hb Saturation)
0
20
40
60
80
100
90
95
100
Minimum
Median
Maximum
Min (Man Artfct Remvl)
Med (Man Artfct Remvl)
Max (Man Artfct Remvl)

Southampton data

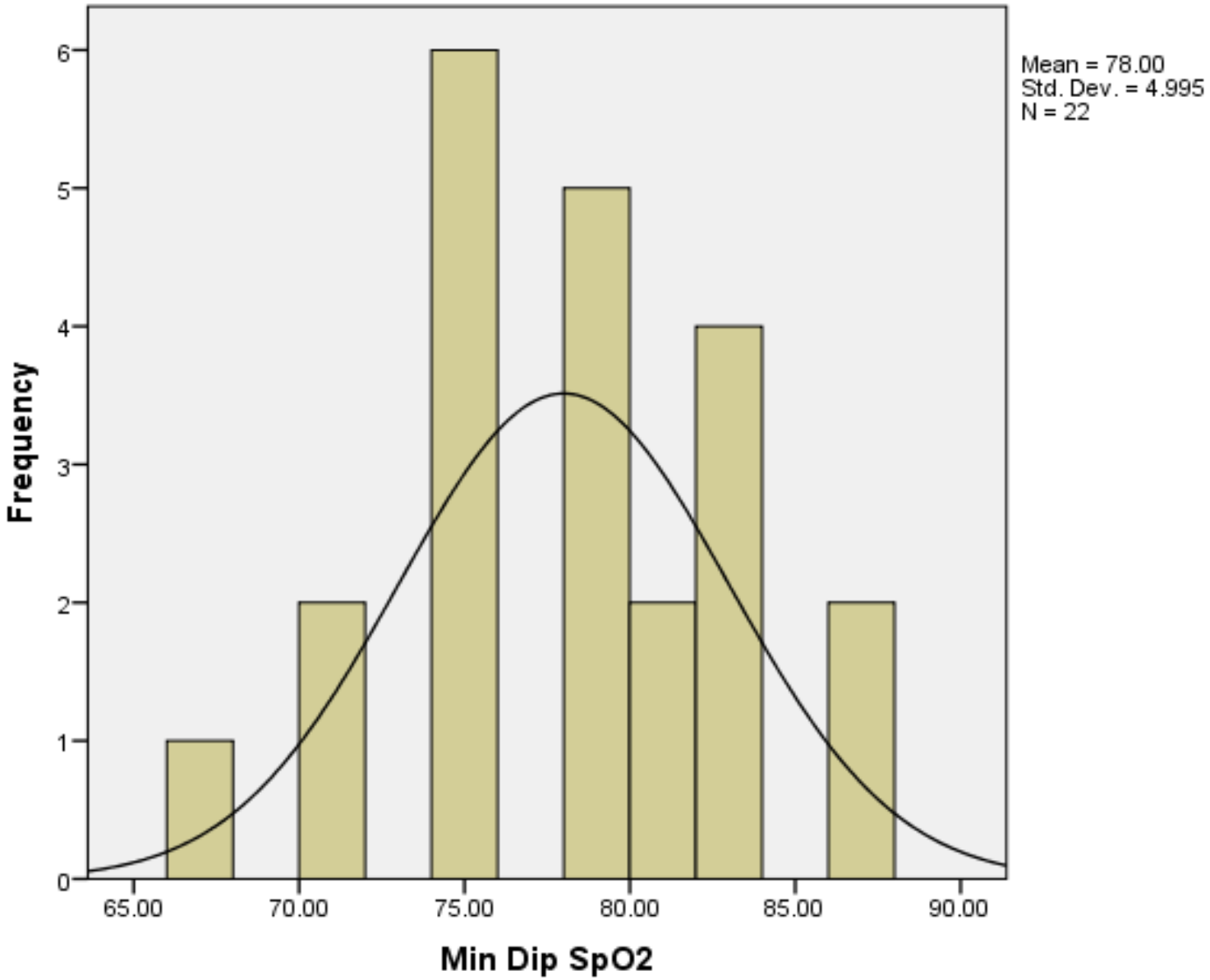
- Normal infants <6months age
- Home pulse oximetry masimo Rad8
- Minimum 4 hours recording including a period of active sleep
- Awake time and artefact excluded from analysis
- Data collected
  - Mean saturations
  - Minimum saturations
  - Time spent with saturations <90%
  - DI_{12}
  - ODI_4

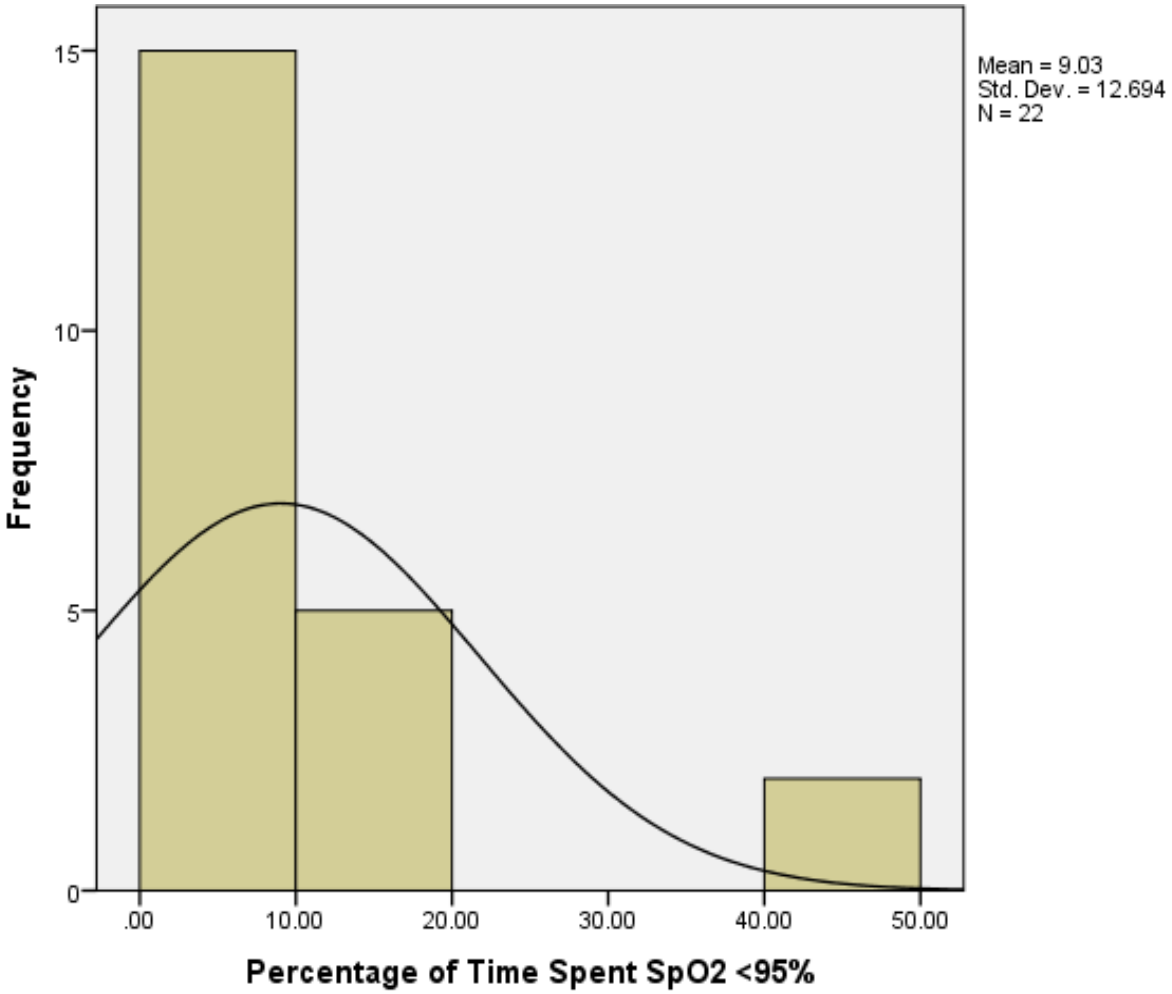
Results

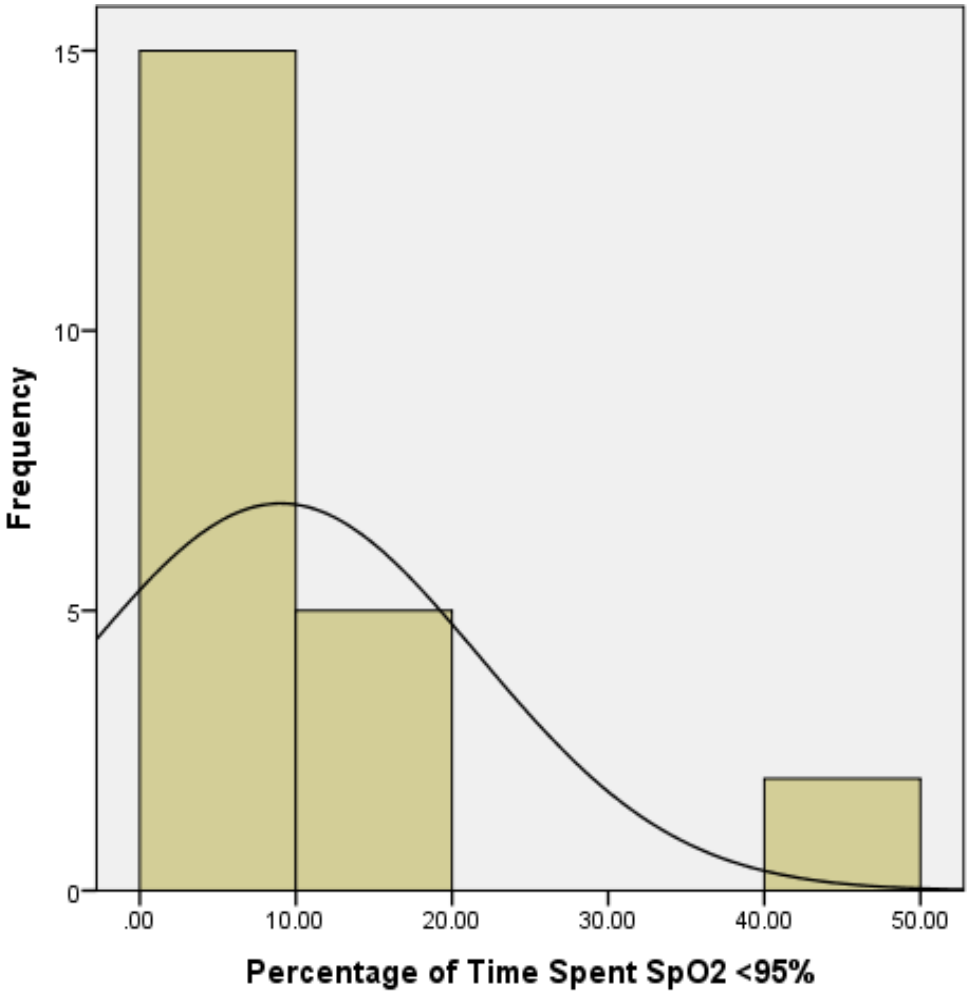
- 26 infants recruited
- 22 successful studies
- Mean age 21 days

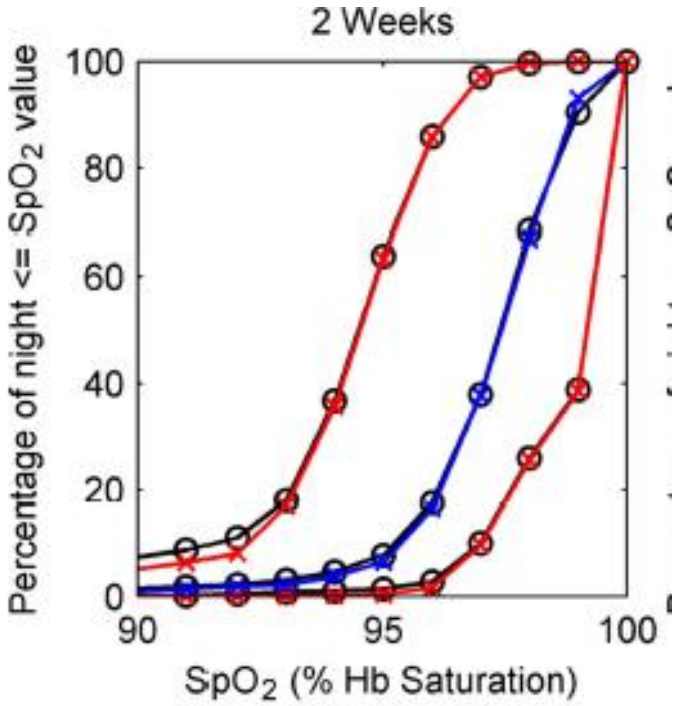


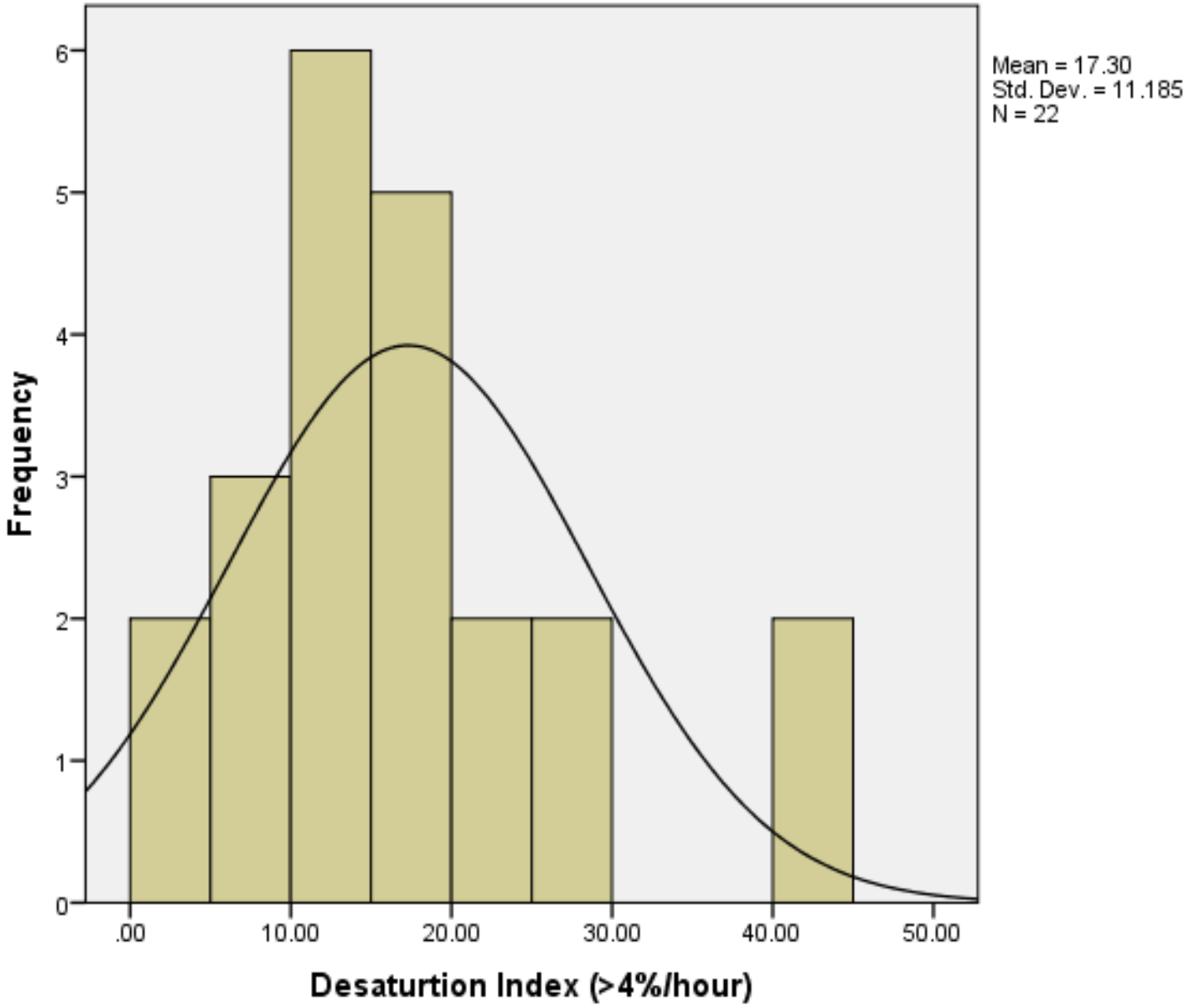
- Mean saturations 97.2% (94.9-100%)

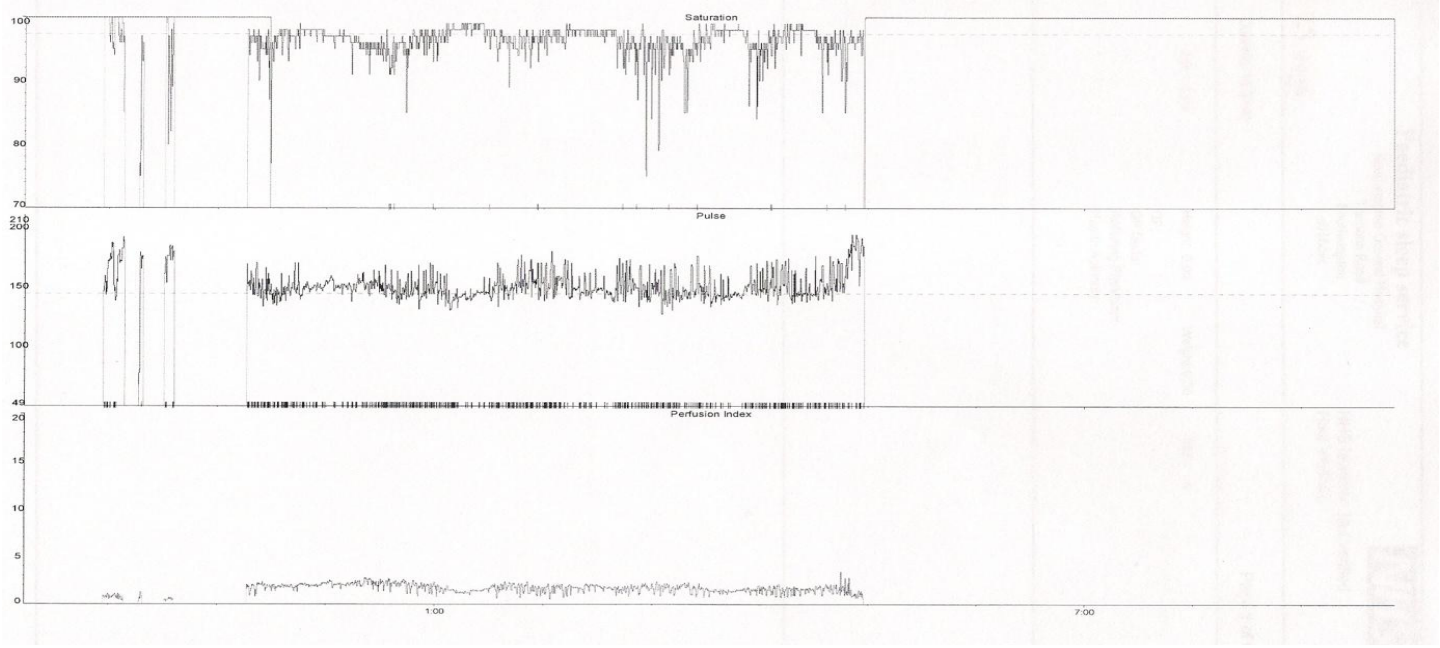

Mean = 78.00
Std. Dev. = 4.995
N = 22
Frequency
0
1
2
3
4
5
6
65.00
70.00
75.00
80.00
85.00
90.00
Min Dip SpO2

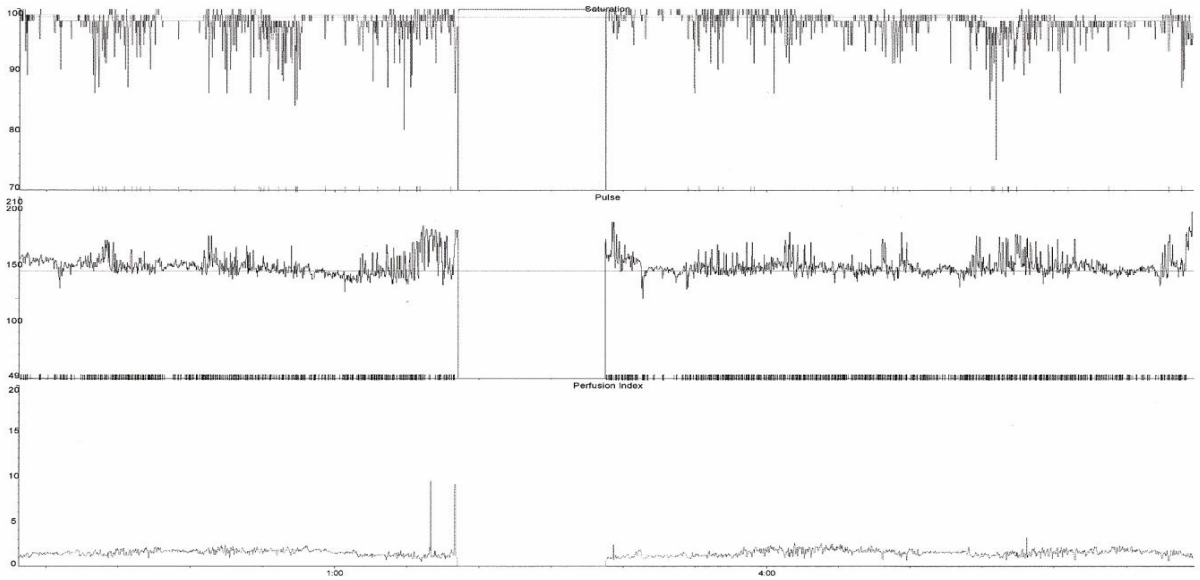

Mean = 9.03
Std. Dev. = 12.694
N = 22
Frequency
15
10
5
0
.00
10.00
20.00
30.00
40.00
50.00
Percentage of Time Spent SpO2 <95%


Mean = 9.03
Std. Dev. = 12.694
N = 22
Frequency
15
10
5
0
.00
10.00
20.00
30.00
40.00
50.00
Percentage of Time Spent SpO2 <95%


2 Weeks
Percentage of night <= SpO2 value
100
80
60
40
20
0
90
95
100
SpO2 (% Hb Saturation)


Mean = 17.30
Std. Dev. = 11.185
N = 22
Frequency
0
1
2
3
4
5
6
.00
10.00
20.00
30.00
40.00
50.00
Desaturtion Index (>4%/hour)


Saturation
100
90
80
70
Pulse
210
200
150
100
49
Perfusion Index
20
15
10
5
0
1:00
7:00


Saturation
100
90
80
70
Pulse
210
200
150
100
49
Perfusion Index
20
15
10
5
0
1:00
4:00

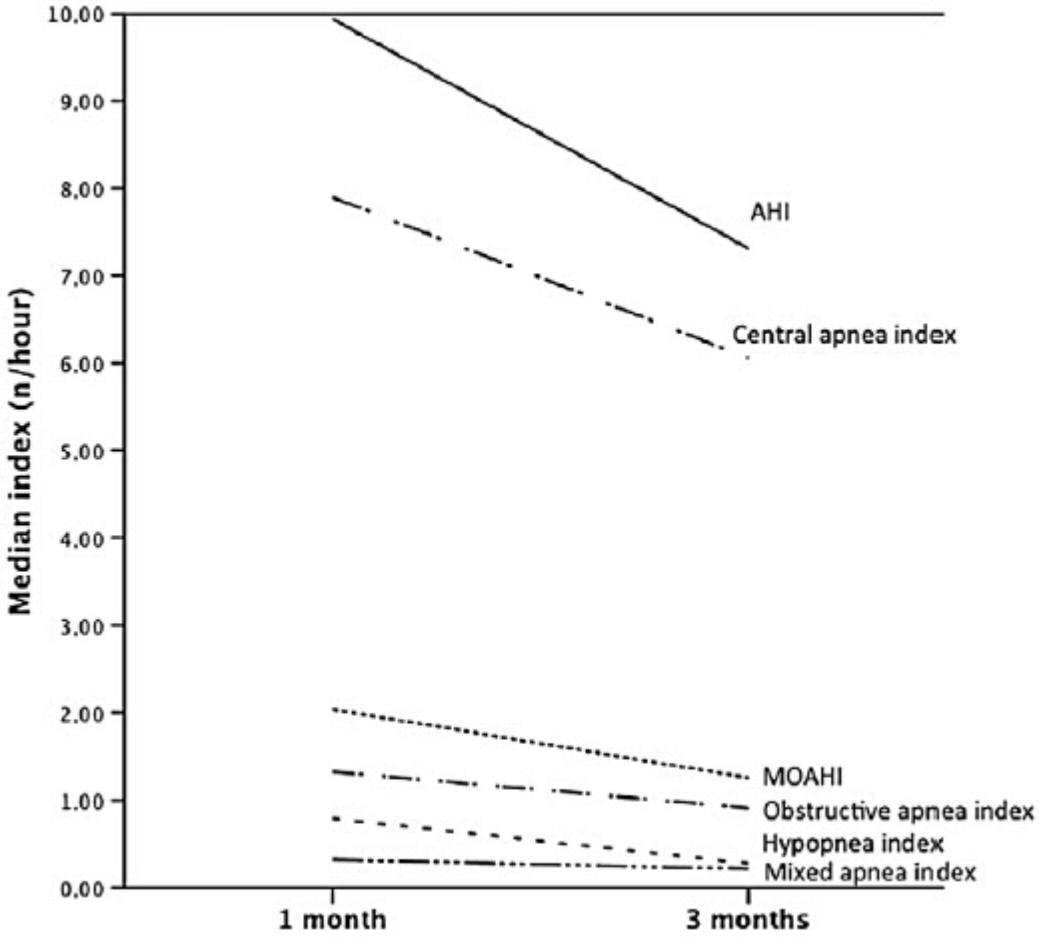


Fig. 1. Changes of respiratory indices between the ages of 1 and 3 months.

PE Brockmann et al Sleep Medicine 2013

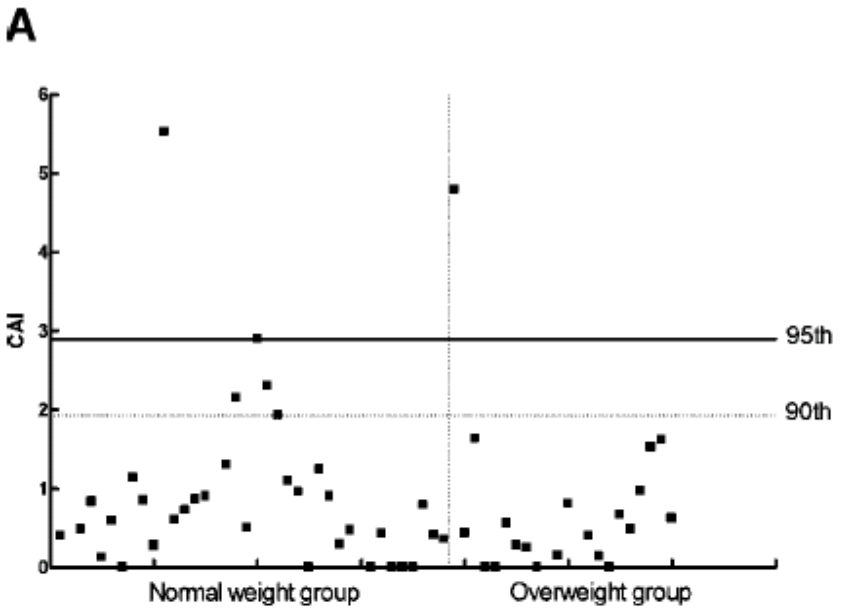
Summary of oximetry

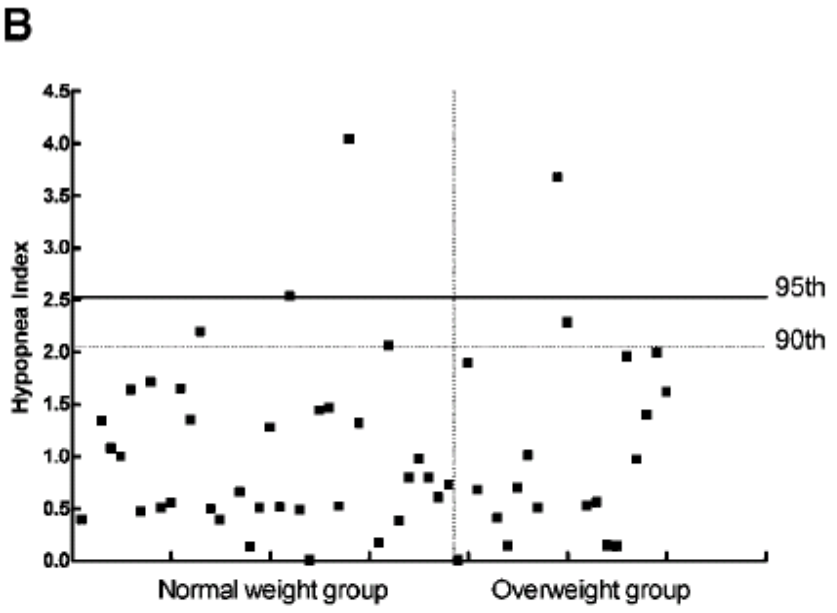
- Healthy children over 1 year should have
  - Saturations above 95%
  - < 4 desaturations >4%/hour
  - < 2 clusters of desaturations
  - < 1 desaturation below 90%
- Infants < 3months
  - Clusters of desaturations are common
  - Mean 4% desaturation index = 17
- Best predictor of OSA based on PPV = 4% desaturation index >4

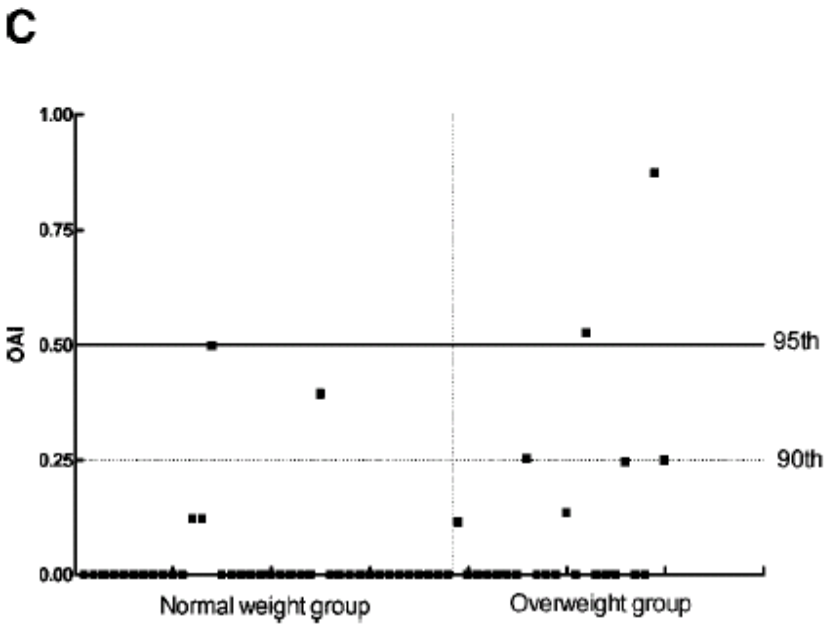
Cardiorespiratory sleep studies

- What is normal
- What is a clinically significant AHI?

Variable	Current study	Marcus et al.[6,7]	Uliel et al.[8]	Traeger et al.[9]	Montgomery-Downs et al.[10]
N	60	50	70	66	388
Age group					
Mean ± SD	11.7 ± 2.6	9.7 ± 4.6	7.9 ± 4.4	6.6 ± 1.9	6.8
Range	7.1–16.6	1.1–17.4	1.0–15.0	2.5–9.4	6.0–8.6
TST (hr)					
Mean ± SD	7.8 ± 0.8	6.0 ± 1.6	6.5 ± 1.2	7.7 ± 0.9	7.9 ± 0.7
Sleep efficiency (%)					
Mean ± SD	80.5 ± 8.5	NP	90.8 ± 6.5	89.0 ± 8.0	90 ± 7.0
CAI					
Mean ± SD	0.85 ± 1.06	NP	0.4	NP	0.45 ± 0.49
Range	0.00–5.53				0.00–3.40
CAI^2					
Mean ± SD	0.29 ± 0.59	NP	NP	0.08 ± 0.14	NP
Range	0.00–4.11			0.0–6.0	
OAI					
Mean ± SD	0.06 ± 0.16	0.10 ± 0.50	0.02	0.01 ± 0.03	0.05 ± 0.11
Range	0.00–0.87	0.00–3.10		0.00–0.10	0.00–0.90
oAHI					
Mean ± SD	0.08 ± 0.17	0.20 ± 0.60	NP	0.23 ± 0.31	NP
Range	0.00–0.87				
RDI					
Mean ± SD	1.98 ± 1.39	NP	NP	0.4 ± 0.6	0.68 ± 0.75
Range	0.14–7.18			0.0–4.0	0.00–6.60
Total arousal index					
Mean ± SD	6.1 ± 1.8	NP	5.29 ± 3.49	11.2 ± 4.3	9.5 ± 5.3
Range	2.7–10.9			5.4–21.5	NP







Verhulst et al Pediatric Pulmonology 2007

Clinically important AHI

- OAHI associated with
  - adverse neurocognitive outcomes
  - altered cerebral blood flow and neuronal function
    - Not controlled for SES, obesity, race
    - Not controlled for time in bed
  - Increased cardiac strain – AHI >5

- Risks of treatment
  - Cost
  - Adherence to treatments
  - Risk of surgery
  - Medication risks
- Not treating risks affecting trajectory of child's developmental gains
  - Intelligence
  - Executive function
  - Social interactions
  - Affect lifetime academic and social achievements

CHAT study

- OAI >1 or OAHI >2
- Improvements in both groups
- No change in executive function
- Improvements in behaviour (caregiver and teacher)
- Improved QOL
- Reduced symptoms

Marcus CL et al NEJM 2012

- OAHI > 5 – refer for surgery
- OAHI 2-5
  - Review clinically
  - Decision to operate based on
    - Comorbidities
    - Family concerns and effect on daily function
  - Sometimes advise topical steroids

Screening for OSA

Table 1 Indications for paediatric respiratory investigations

- Diagnosis of OSA unclear or inconsistent
- Age < 2 years
- Weight < 15 kg
- Down's syndrome
- Cerebral palsy
- Hypotonia or neuromuscular disorders
- Craniofacial anomalies
- Mucopolysaccharidosis
- Obesity (body mass index > 2.5 standard deviation scores or > 99th centile for age and gender
- Significant co-morbidity such as congenital heart disease, chronic lung disease
- Residual symptoms after adenotonsillectomy

Aim: To determine the role of parental video footage where the history of apnoeas was unclear

Table 1 Indications for paediatric respiratory investigations

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Considering how severe the problem is when your child experiences it and how often it happens over the past **six months for your child**, please rate each item below on how "bad" it is by circling the number that corresponds with how you feel using this scale: If a certain question is not a problem for your child, please circle"0". Please try not to miss any questions.	No problem	Very mild problem	Mild or slight problem	Moderate Problem	Severe Problem	Problem as bad as it could be
1. Snoring loudly during sleep	0	1	2	3	4	5
2. Irregular or stopped breathing (apnoea) during sleep	0	1	2	3	4	5
3. Day time sleepiness	0	1	2	3	4	5
4. Noisy breathing during the day	0	1	2	3	4	5
5. Breathing through the mouth during the day	0	1	2	3	4	5
6. Problems with poor appetite, or poor eating habits (choking on food etc)	0	1	2	3	4	5
7. Frequent ear ache or ear infections	0	1	2	3	4	5
8. Repeated short-term throat infections that last less than 2 weeks	0	1	2	3	4	5
9. Constant, or chronic, throat infections that last more than 2 weeks	0	1	2	3	4	5
10. Many phone calls to the doctor or NHS direct	0	1	2	3	4	5
11. Many visits to the family doctor or A&E department	0	1	2	3	4	5
12. Taking antibiotics over and over for less than 2 weeks at a time	0	1	2	3	4	5
13. Taking antibiotics for more that 2 weeks straight	0	1	2	3	4	5
14. Missing school days due to sore throats	0	1	2	3	4	5

Results

- 18 cases documented where parental video evidence secured a diagnosis
- In all cases T14 questionnaires improved post surgery

- Indications for referral
  - Not sure clinically
  - OSA unlikely but parents concerned ++
  - Soft symptoms (snoring + restless sleep ++)
- All children have polygraphy (somnoscreen/somnotouch) + oximetry (masimo)

Health Economics

- Using criteria of 4% ODI 10 / 19 children with OAHI >2 were picked up
- Cost of oximetry on all 75 children (£250 per study) = £18,750
- Cost of CRSS on 65 negative oximetry studies (£800 per study) = £52,000
- Total cost = £70,750
- All 75 just have CRSS= £60,000

Conclusion

- Abnormal oximetry highly predictive of OSA in children >1 year
  - ODI_4 >4
- Central apnoeas common in first 3 months of life elevating desaturation indices and clusters of desaturation
- Need to consider referral pathways when balancing use of oximetry as a screening tool for OSA.

Discussion

- What parameters are you using?
- Where do you see the role of the 3% ODI?
- What are you doing with infants?
- What is the role of oximetry as a screening tool for OSA?