

Actigraphy in Children

Janet Lam, MD, MHS

Medical Director of the Sleep Center

Valerie Paasch, PhD

Director of Behavioral Sleep Services

We are all born with great potential.
Shouldn't we all have the chance to achieve it?



Kennedy Krieger Institute
UNLOCKING POTENTIAL

Conflicts of Interest

- We have no conflicts of interest or commercial affiliations.



Learning Objectives

- Understand the value of actigraphy in sleep assessment
- Learn about the advantages and disadvantages of actigraphy data
- Discover how actigraphy compares to other measures of sleep.



What is actigraphy?

- A non-invasive, wrist accelerometer that measures sleep-wake information over several days outside of the lab
- Mathematic algorithms estimate sleep/wake cycles from limb movement activity

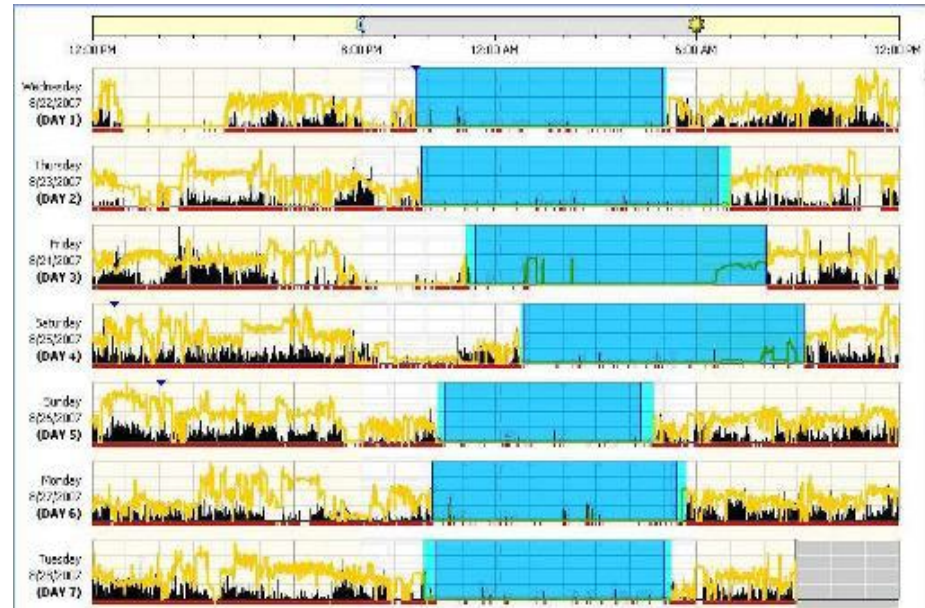


Sleep-challenged CR tech editor Allan St. John donned half a dozen sleep trackers before bed for 34 nights in his quest for uninterrupted slumber. See which gave him the rest he needed.

40 CR.ORG JANUARY 2022

(Consumer Reports, January 2022)

Actigraphy



Kennedy Krieger Institute
UNLOCKING POTENTIAL

The Old Standby

WEEK 3454 TWO WEEK SLEEP DIARY #2

INSTRUCTIONS:

1. Write the date, day of the week, and type of day: Work, School, Day Off, or Vacation.
2. Put the letter "C" in the box when you have coffee, cola or tea. Put "M" when you take any medicine. Put "A" when you drink alcohol. Put "E" when you exercise.
3. Put a line (|) to show when you go to bed. Shade in the box that shows when you think you fell asleep.
4. Shade in all the boxes that show when you are asleep at night or when you take a nap during the day.
5. Leave boxes unshaded to show when you wake up at night and when you are awake during the day.



SAMPLE ENTRY BELOW: On a Monday when I awoke, I jogged on my lunch break at 1 PM, had a glass of wine with dinner at 6 PM, fell asleep watching TV from 7 to 8 PM, went to bed at 10:30 PM, fell asleep around midnight, woke up and couldn't get back to sleep at about 4 AM, went back to sleep from 5 to 7 AM, and had coffee and medicine at 7:00 in the morning.

Today's Date	Day of the week	Type of Day Work, School, Off, Vacation	Noon	1PM	2	3	4	5	6PM	7	8	9	10	11PM	Midnight	1AM	2	3	4	5	6AM	7	8	9	10	11AM
sample	Mon.	Work		E					A																	
③ 2/15/16	M	S																								
2/16/16	T	S																								
2/17/16	W	S																								
2/18/16	Th	S																								
2/19/16	F	OFF																								
2/20/16	S	OFF																								
2/21/16	S	OFF																								
④ 2/22/16	M	S																								
2/23/16	T	S																								
2/24/16	W	S																								
2/25/16	Th	S																								
2/26/16	F	OFF																								
2/27/16	S	OFF																								
2/28/16	S	OFF																								

Scanned by CamScanner

How does actigraphy compare to sleep logs?



NIH Public Access

Author Manuscript

Behav Sleep Med. Author manuscript; available in PMC 2011 November 2.

Published in final edited form as:

Behav Sleep Med. 2011 June ; 9(3): 184–193. doi:10.1080/15402002.2011.583906.

Defining the Roles of Actigraphy and Parent Logs for Assessing Sleep Variables in Preschool Children

Janet C. Lam,

Department of Pediatrics, University of Maryland

E. Mark Mahone,

Department of Neuropsychology, Kennedy Krieger Institute, Baltimore

Thornton B. A. Mason, and

Division of Neurology and Sleep Center, The Children's Hospital of Philadelphia

Steven M. Scharf

Sleep Disorder Center, Division of Pulmonology and Critical Care, University of Maryland, Baltimore



Kennedy Krieger Institute
UNLOCKING POTENTIAL

How does actigraphy compare to sleep logs?

- 59 children ages 3-5 years attending full-time day care
- Actigraphy watch worn for 1 week
- Parents and day care workers completed sleep logs



How does actigraphy compare to sleep logs?

- Results
 - Parents overestimated night time sleep (13-22%)
 - No difference in sleep onset times
 - Parents reported later rise times on weekend and fewer night time wakings



How does actigraphy compare to sleep logs?

- Conclusions
 - Sleep logs best to assess daytime sleep onset and TST
 - Actigraphy best to assess night time sleep offset and TST



How does it compare to polysomnography?

- Marino et al (2013) compared actigraphy and polysomnography data during one overnight in the lab
- 77 adults were studied for 2-3 nights
- AW-64 (Minimitter) and Actiwatch Spectrum (Philips/Respironics) devices
- Synchronization of PSG and actigraphy devices
- Epoch-by-epoch analysis and sleep parameter analysis was performed to determine accuracy, sensitivity, and specificity.



How does it compare to polysomnography?

Table 3—Univariable and multivariable GEE models assessing the effect of gender, age, and time of sleep on accuracy, sensitivity, and specificity

	Accuracy		Sensitivity		Specificity	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
Overall	0.865	n/a	0.965	n/a	0.333	n/a
Gender						
Male	0.854	0.428	0.962	0.237	0.336	0.752
Female	0.893		0.971		0.325	
Time of Sleep						
Day	0.866	0.105	0.972	0.030	0.325	0.802
Night	0.865		0.963		0.334	
Insomnia						
Yes	0.833	0.516	0.946	0.132	0.347	0.680
No	0.869		0.967		0.331	

These models are adjusted for age. The findings for age are presented in Figure 2. The P-values for the effect of age on accuracy, sensitivity and specificity were not significant.



How does it compare to polysomnography?

- High accuracy (86%) suggests actigraphy is a reasonable measure of sleep
- Sensitivity of actigraphy does not vary between subjects and is above 90%
- Specificity is highly variable across subjects, suggesting difficulty detecting wake patterns between individuals
- Specificity in insomnia patients with high SE is higher than with low SE
- Specificity highest in healthy, younger patients



How does it compare to polysomnography?

- As sleep efficiency declines with age, accuracy is slightly reduced
- Accuracy below 80% in older women with insomnia
- Actigraphy overestimated WASO
- Overall, actigraphy is useful and valid for estimating TST and WASO



AASM Clinical Practice Guideline

- Prior practice parameter (2007) established validity of actigraphy to assess sleep in a normal, healthy adult population
- Updated recommendations for patients with suspected/diagnosed sleep disorders or circadian rhythm sleep-wake disorders based on systematic literature review
- Grading of Recommendations Assessment, Development and Evaluation (GRADE) process
 - Quality of evidence, balance of benefit vs harm, patient values and preferences, resource use
- Purpose: compare actigraphy to sleep logs and PSG to determine if information is distinct from patient report and consistent with PSG

Smith et al, 2018, J of Clinical Sleep Med, 14(7)



Kennedy Krieger Institute
UNLOCKING POTENTIAL

AASM Clinical Practice Guideline

- Strong Recommendation (follow under most circumstances)
- Conditional Recommendations (low degree of certainty, clinical judgment needed)



AASM Clinical Practice Guideline

Recommendation #1: We suggest clinicians use actigraphy to estimate sleep parameters in adult patients with **insomnia** (Conditional)

Recommendation #2: We suggest clinicians use actigraphy in the assessment of pediatric patients with **insomnia** disorder. (Conditional)



AASM Clinical Practice Guideline

Recommendation #3: We suggest that clinicians use actigraphy in the assessment of adult patients with **circadian rhythm sleep-wake disorder**. (Conditional)

Recommendation #4: We suggest that clinicians use actigraphy in the assessment of pediatric patients with **circadian rhythm sleep-wake disorder**. (Conditional)



AASM Clinical Practice Guideline

Recommendation #5: We suggest that clinicians use actigraphy integrated with home sleep apnea test devices to estimate total sleep time during recording (in absence of alternative, objective measurements of TST) in adult patients suspected of **sleep-disordered breathing**. (Conditional)



AASM Clinical Practice Guideline

Recommendation #6: We suggest that clinicians use actigraphy to monitor TST prior to testing with MSLT in adult and pediatric patients with suspected central disorders of **hypersomnolence**.
(Conditional)



AASM Clinical Practice Guideline

Recommendation #7: We suggest that clinicians use actigraphy to estimate TST in adult patients with suspected **insufficient sleep syndrome**.
(Conditional)



AASM Clinical Practice Guideline

Recommendation #8: We recommend that clinicians not use actigraphy in place of EMG for the diagnosis of **PLMD** in adult and pediatric patients. (Strong)



Kennedy Krieger Institute
UNLOCKING POTENTIAL

Are alternatives like FitBit accurate?



[J Med Internet Res.](#) 2019 Nov; 21(11): e16273.

PMCID: PMC6908975

Published online 2019 Nov 28. doi: [10.2196/16273](#)

PMID: [31778122](#)

Accuracy of Wristband Fitbit Models in Assessing Sleep: Systematic Review and Meta-Analysis

Monitoring Editor: Gunther Eysenbach

Reviewed by Luiz Menna-Barreto, Anis Davoudi, Iskra Mircheva, and Ram Bajpai

[Shahab Haghayegh](#), MS,^{✉1} [Sepideh Khoshnevis](#), MD, PhD,¹ [Michael H Smolensky](#), PhD,^{1,2} [Kenneth R Diller](#), SCD,¹ and [Richard J Castriotta](#), MD, FAASM, FCCP³

Are alternatives like FitBit accurate?

Systematic Review and Meta-analysis

- 3085 candidate articles
 - 22 articles met criteria for systematic review
 - 8 articles provided quantitative data for meta-analysis



Are alternatives like FitBit accurate?

Results

- Overestimates total sleep time by 7-67 minutes ($p < 0.001$)
- Overestimates sleep efficiency by 2-15% ($p < 0.001$)
- Underestimates WASO by 6-44 minutes ($p < 0.001$)
- May correctly identify sleep onset
- Correctly identified sleep epochs
- Use of heart rate variability and body movement increases accuracy

Haghighat 2019

Are alternatives like FitBit accurate?

Conclusions

- Fitbit shows promising performance in differentiating wake from sleep
- Fitbit is an economical way to obtain gross estimates of sleep parameters
- Not a substitute for PSG



Haghighyeh 2019

Case #1

6yo non-verbal child with autism presents to sleep clinic for night wakings. Parent reports he sleeps alone and falls asleep independently. Mom only goes in his room if he is crying. He is difficult to wake in the morning and falling asleep at school and sometimes has behavioral problems.

Would you order actigraphy?



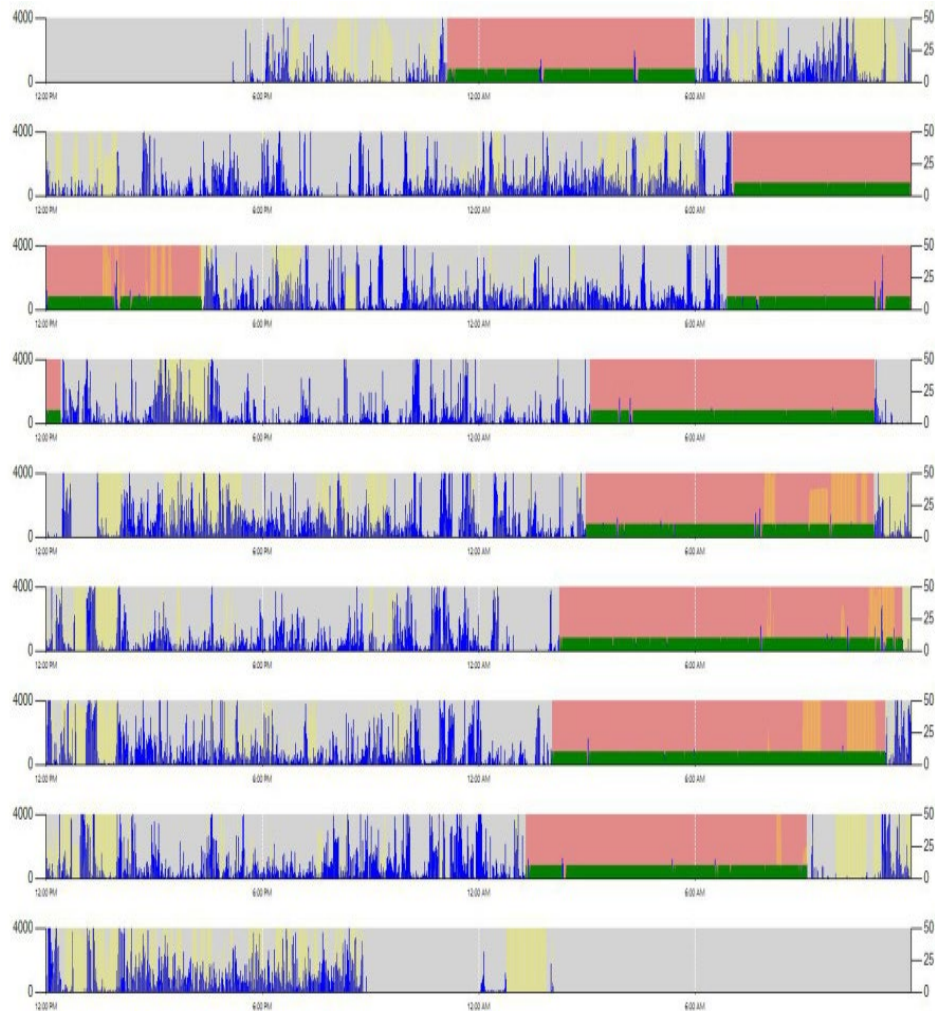
Case #2

15yo female presents to sleep clinic for daytime fatigue. She reports having trouble falling asleep, and will watch YouTube videos on her phone until she falls asleep. She also reports waking at night and will turn her phone on to watch more videos if she cannot return to sleep. She has difficulty waking in the morning for school, but no difficulty on weekends and wakes spontaneously.

Would you order actigraphy?



A Look at a Pediatric Actigraphy Service



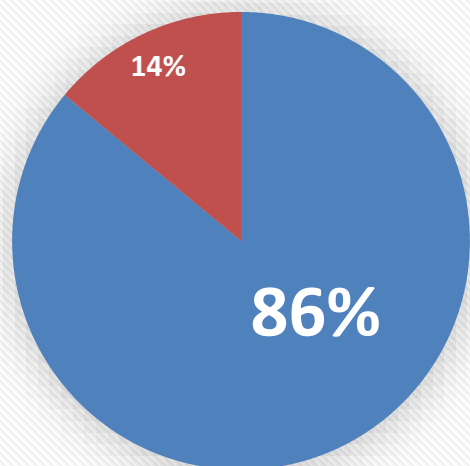
Our Actigraphy Service Design

- Based in the outpatient Pediatric Psychology Clinic
- Toddlers through young adults
- Many patients with neurodevelopmental disabilities, complex emotional/ behavioral profiles, and complicated medical histories
- Typically 12 actigraphs in use across 2 locations

Our Actigraphy Service Design

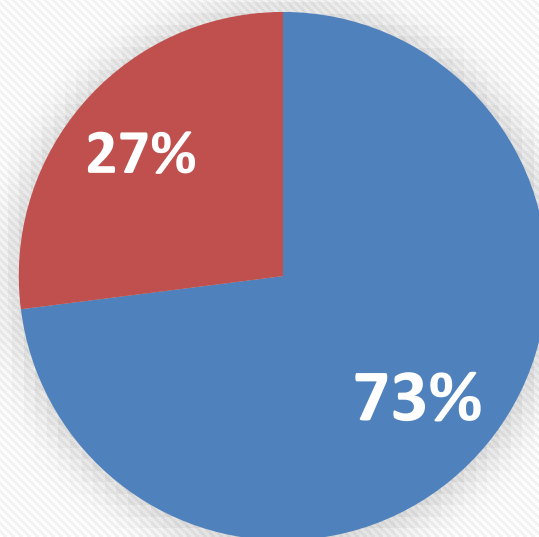
- 333 referrals between January 2020- October 2023
 - 91 referrals in the past year

Source of Referrals



■ Sleep Clinic ■ Other Referral Source

Appointment Scheduled



A Model of Service

- Scheduling
 - Separate waitlist to expedite scheduling
- Pre-appointment:
 - Complete chart review & initialize actigraph
- Appointment 1:
 - Complete updated sleep assessment
 - Orient family to actigraph and sleep log
 - Sign contract to return actigraph
 - Place actigraph on child
 - Schedule follow up appointment



Materials Used with Families

What is Actigraphy?

Actigraphy is a small electrical device worn on the wrist like a watch. It is equipped with specialized movement detectors that take measurements repeatedly over the course of the day to give an overall picture of your activity levels. In general, we tend to be much less active during periods of rest than in our waking hours. Based on this principle, data about our daily movements can be used to determine when and how we sleep.

This allows your sleep specialist to obtain an accurate sketch of your general patterns of sleep and wake. We can estimate how much time you spend awake, how long you sleep, and what your sleep schedule looks like. It can help us assess sleep issues and measure your success with treatment. Actigraphy is non-invasive and easy for you to wear, just like a watch on your wrist. It lets us see how you sleep in your regular environment. Wearing a small electronic device while going about your day-to-day activities can help the sleep specialist evaluate your sleep.

****Remember to remove your actigraph when you bathe, shower, do the dishes, and/or swim.

Materials Used with Families

Actigraphy Sleep Log Addendum

Date	Time in bed	Time out of bed	Times Actigraph Off	Time of night waking	Time of naps	Notes:
<i>Example:</i>	<i>10:00pm (tonight)</i>	<i>6:00am (tomorrow morning)</i>	<i>4:15-4:45pm (pool) 9:00-9:20pm (shower)</i>	<i>1:10-1:55am</i>	<i>1:00 – 2:00pm</i>	

Materials Used with Families

Actigraphy Agreement

The Pediatric Psychology Consultation Program has loaned actigraphy equipment to _____ (name) to assist with my ongoing treatment. I agree to return this equipment _____ (equipment ID) and understand that I will be billed for the cost of a replacement should I fail to return it.

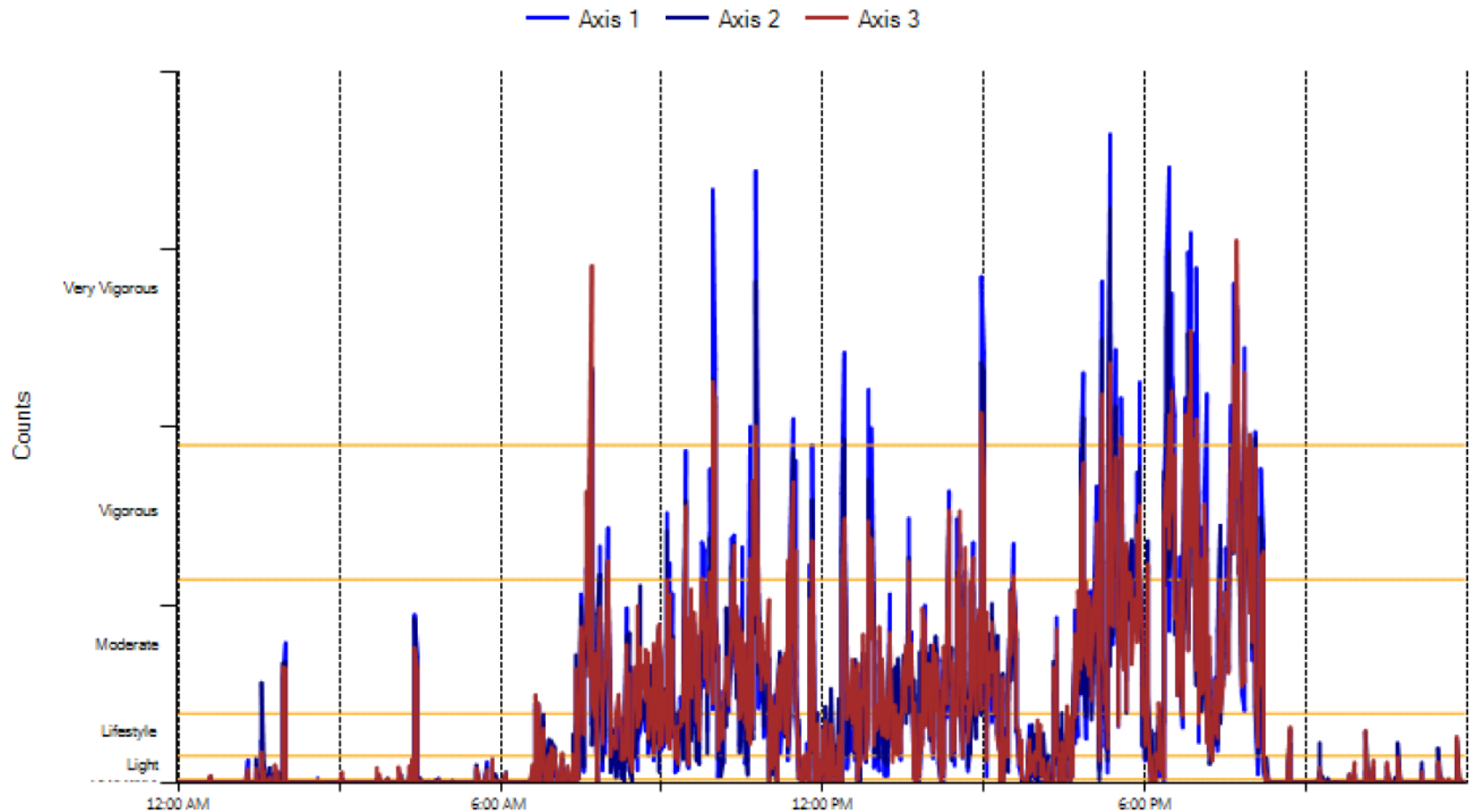
Child/Adolescent Signature

Parent Signature

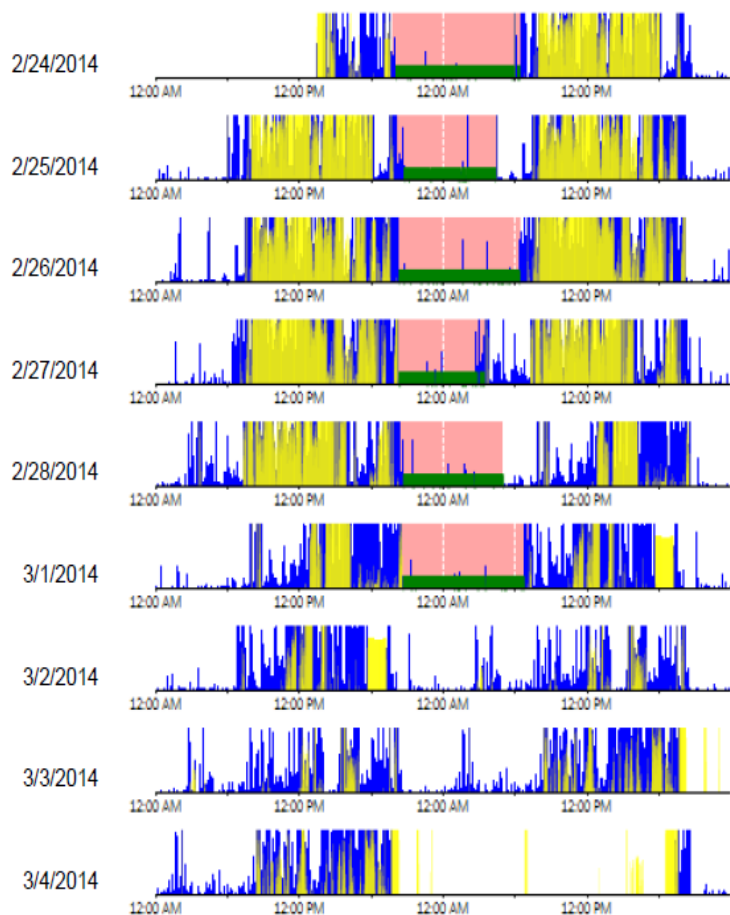
Therapist Signature

Date

Materials Used with Families



Materials Used with Families



Sleep Period Breakdown

Sleep Algorithm Used: Sadeh

In Bed	Out Bed	Latency (min)	Efficiency	Total Time in Bed (min)	Total Sleep Time (TST) (min)	Wake After Sleep Onset (WASO)	# of Awakenings	Avg Awakening (min)
2/24/2014 7:45 PM	2/25/2014 6:50 AM	20	86.47%	665	575	70	14	6.43
2/25/2014 8:00 PM	2/26/2014 4:30 AM	49	81.57%	510	416	45	8	11.75
2/26/2014 8:00 PM	2/27/2014 6:30 AM	20	87.14%	630	549	61	23	3.52
2/27/2014 8:15 PM	2/28/2014 3:30 AM	5	82.3%	435	358	72	17	4.53
2/28/2014 8:30 PM	3/1/2014 5:00 AM	12	91.96%	510	469	29	8	5.13
3/1/2014 8:40 PM	3/2/2014 7:21 AM	1	89.39%	641	573	67	14	4.86
3/5/2014 8:30 PM	3/6/2014 6:30 AM	13	77.67%	600	466	121	19	7.05
3/6/2014 8:00 PM	3/7/2014 5:47 AM	5	76.49%	587	449	133	24	5.75
3/9/2014 8:15 PM	3/10/2014 3:30 AM	0	77.01%	435	335	100	17	5.88
8:12 PM	5:29 AM	13.89	83.33%	557	465.56	77.56	16	5.72

A Model of Service

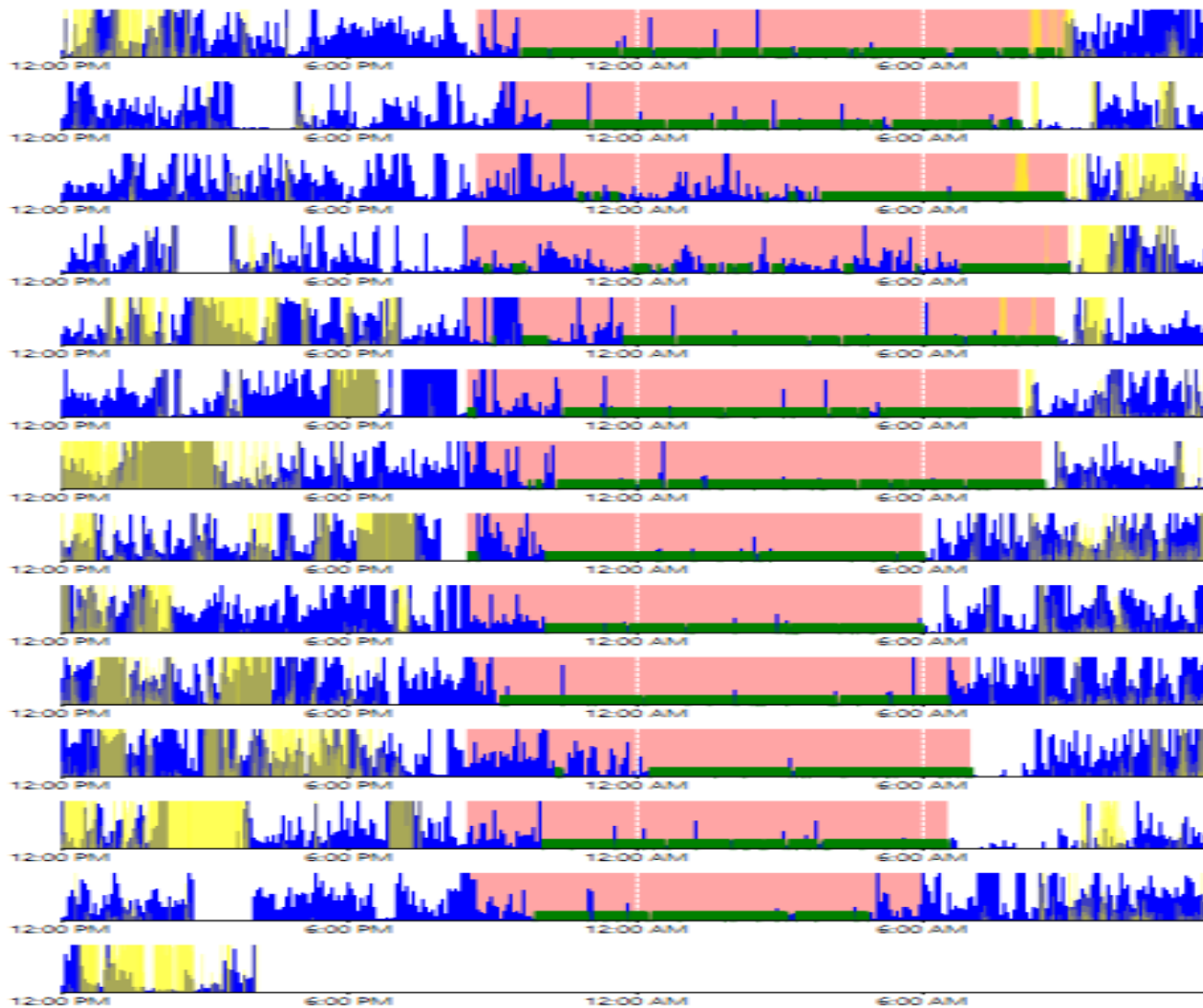
- Appointment 2:
 - Download data & generate graphs
 - Complete sleep analysis with information from sleep log
 - Review data & give family a copy of output
 - Make behavioral sleep recommendations
- After the appointment:
 - Share data with referral source
 - Follow up in Sleep Clinic or with referring provider for additional recommendations
- Families can repeat actigraphy in the future

Case #3

10yo with history of ASD, ADHD, anxiety, and insomnia

- Prior PSG- Mild OSA
- Restlessness- Supplementing with iron
- Consistent routine & in bed at 8:45pm
 - Electronics off at 8:00pm
- Unsure about SOL and waking overnight
- Wakes independently at 6:00am
- No napping
- Increased daytime emotionality

Actigraphy Data



Sleep Analysis

- Ave. Time in Bed: 8:34pm
- Ave. Time out of Bed: 7:35am
- Ave. SOL: 61.69 (Range- 1-128 minutes)
- Ave. Efficiency: 66.96% (Range- 28%- 81%)
- Ave TST: 438.2 minutes (Range: 210-551 minutes)
 - Ave: 7.3 hours
 - Goal: 9-12 hours in childhood
- Ave WASO: 161.4 minutes (Range- 45-519 minutes)



Behavioral Sleep Recommendations

- Education on factors potentially impacting sleep.
- Adjusting bedtime is not a current option for the family.
 - May need to check on her before parents go to bed.
- It seems she is spending a lot of time engaging in activities, either after bedtime or overnight.

Behavioral Sleep Recommendations

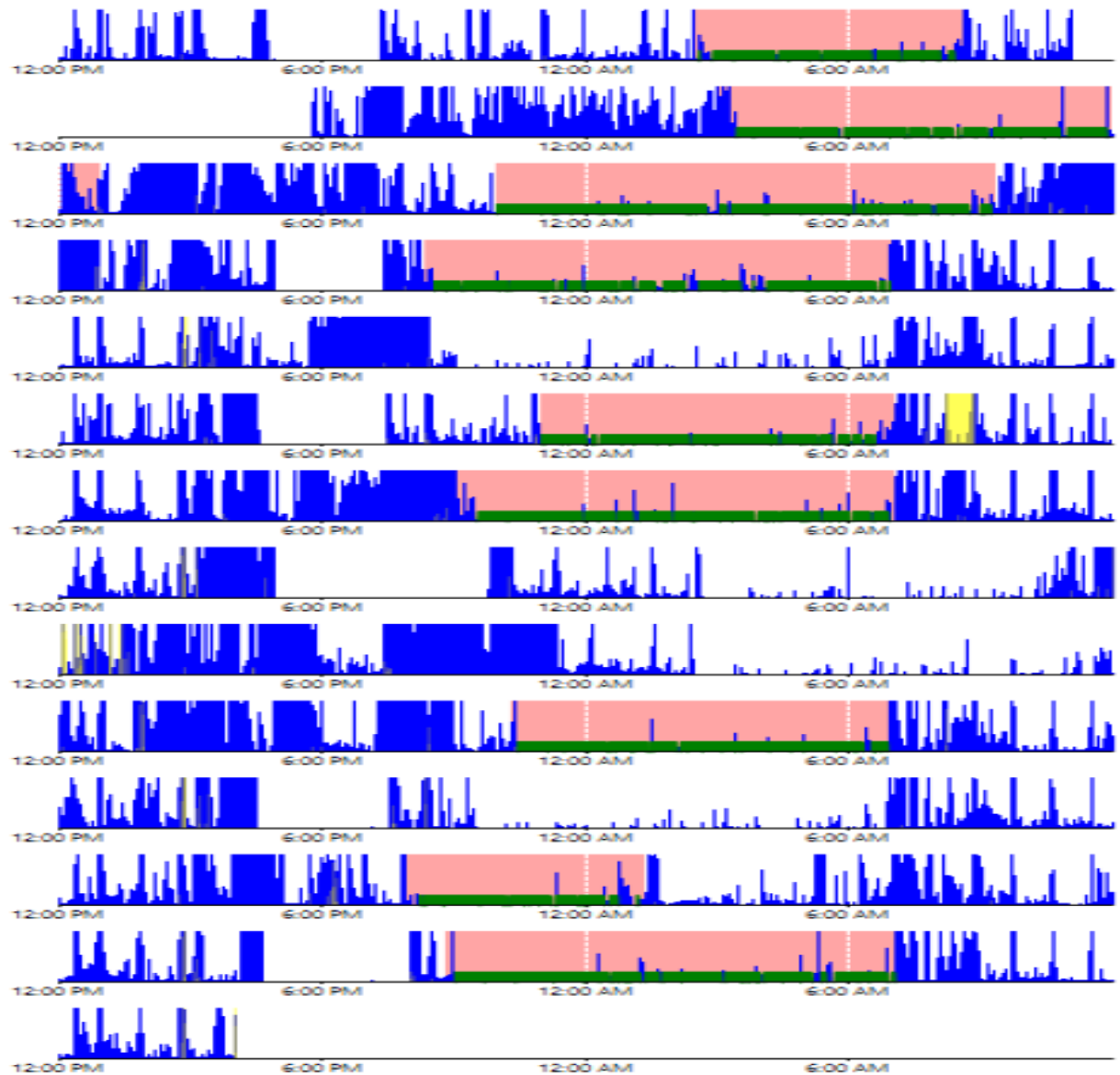
- Blackout curtains if light is contributing to early morning waking.
- Continue managing anxiety, especially school-related anxiety.
- Returning to Sleep Clinic.
 - Plan to repeat actigraphy after changes are implemented.

Case #4

14yo with history of ADHD and insomnia

- Taking 1mg melatonin between 7:30-8:00pm
- School days:
 - 8:20 bedtime, 1 hour SOL, wakes 7:00am
- Weekend:
 - 11:00pm bedtime, 15 minute SOL, wakes 11:00am
- Overnight waking:
 - 3-5 times per week between 1:00-3:00am
- Daytime fatigue & difficulty waking
 - No naps

Actigraphy Data



Sleep Analysis

- Ave. Time in Bed: 10:32pm (Range- 7:50pm-3:00am)
- Ave. Time out of Bed: 7:29am (Range- 1:30am-12:50pm)
- Ave. SOL: 13.22 (Range- 4-32)
- Ave. Efficiency: 78.04%
- Ave. TST: 422 minutes (Range: 230-681)
 - Ave.: 7.0 hours
 - Goal: 8-10 hours
- Ave WASO: 102.22 minutes



Behavioral Sleep Recommendations

- Education on sleep need at this age & importance of consistency
- More consistent sleep schedule
 - School day: 9:00pm bedtime
 - Weekend: 12:00am-10:00am sleep schedule (as a starting point)
- Stimulus control with bed & plan for quiet activities during prolonged wakings

Medical Sleep Recommendations

- Family had adjusted sleep schedule and started implementing rec
 - Reporting less overnight wakings
 - Still tired
- Concern for level of movement overnight
 - Ordered iron labs
 - Ordered PSG
- Diagnosed with PLMD

Additional Tips & Lessons Learned

- Ensure the family is really interested in actigraphy, and ensure they know what their responsibilities will be.
- Sometimes the actigraph isn't worn the whole time or the sleep log isn't completed.
 - Don't include missing data in the analysis (Ancoli-Israel et al., 2015)

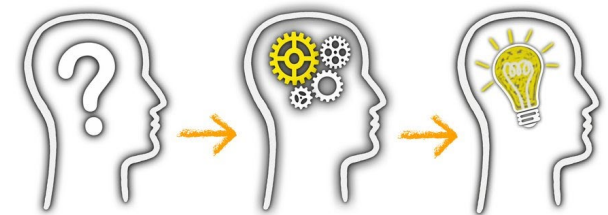


Additional Tips & Lessons Learned

- The actigraph may be difficult to tolerate on the wrist.
 - The ankle can be an alternate placement (Ancoli-Israel et al., 2015)
- Be mindful of “parenting artifact” and adjust analyses accordingly (Ancoli-Israel et al., 2015).
 - Notes on the sleep log can help
- Be aware of abnormal patterns that may indicate device malfunction (Ancoli-Israel et al., 2015).

Additional Tips & Lessons Learned

- Actigraphs will get broken and lost, especially when you're working with kids.
- Scheduling can be challenging when you're planning around illness, school schedules, and time changes.



LESSONS LEARNED

