Evaluation of a Portable Dry Sensor-Based Automatic Sleep Monitoring System

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Background and Specific Aim:

The development and validation of low cost, easy to use, portable sleep recording devices, with algorithms to distinguish between sleep stages and wakefulness, has important implications for sleep medicine and research. A comfortable wireless system has been developed for assessing sleep. The system utilizes dry fabric sensors that require no preparation. The sensors are integrated into a headband that acquires a single channel from the forehead, and transmits to a base station for processing. Sleep stages are scored automatically by a neural network.

The aim of the current study was to compare sleep measures derived from polysomnography (PSG) and from the dry fabric sensor wireless system.

Methods:

Participants:
- 10 adults (6 males, 4 females)
- Aged 33.7 years (± 10.7, SD)
- No sleep complaints

Study Protocol:
- Sleep in the laboratory at participants habitual bedtime
- Concurrent measurement of PSG (EEG: F3xA2, C3xA2, O1xA2, C4xA1; EOG, EMG, EKG) and the wireless dry sensor system worn on the forehead in a headband.
- PSG data were collected with a Cadwell Easy II PSG sampled at 200 samples per second
- Wireless system data were sampled at 128 samples per second
- Sleep records were independently scored by two trained technicians according to Rechtschaffen & Kales.
- Sleep records were scored automatically by the wireless system via its neural network.
- 6 subjects contributed two nights of recordings and 4 subjects one night of recording resulting in 16 total records for analysis.
- The neural network was designed to distinguish light (Stages 1&2), deep (Stages 3&4), REM and wakefulness. Therefore, visual sleep stage scores were grouped into the same categories for analysis.
- Inter-rater agreement was performed on summary statistics of sleep parameters and on a 30 second epoch by epoch basis for agreement/disagreement of stage assignment.

Results:

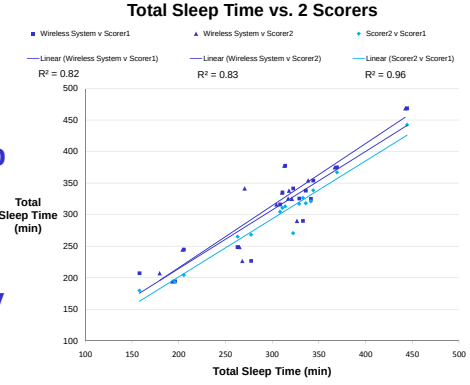
Most sleep summary measures were similar for the visual scorers and the wireless system neural network

Sleep Summary Statistics

	Visual Scorer 1	Visual Scorer 2	Wireless System Neural Network
Total Sleep Time (min)	303.3 ± 17.7	296.2 ± 16.6	310.4 ± 18.0
Sleep Latency (min) to 3 continuous epochs of sleep	31.8 ± 16.0	22.3 ± 9.3	7.5 ± 2.5
Sleep Latency (min) to 10 continuous min of sleep	33.0 ± 16.5	36.4 ± 16.3	31.8 ± 16.1
WASO (min)	27.8 ± 3.7	47.1 ± 8.5	41.7 ± 13.4
Sleep Efficiency (%)	84.5 ± 4.0	82.4 ± 3.6	85.9 ± 3.4
Stage of Sleep (min)			
Light	216.3 ± 14.2	187.3 ± 12.3	201.2 ± 12.0
Deep	24.7 ± 4.6	52.4 ± 6.7	49.3 ± 4.7
REM	62.4 ± 7.0	56.6 ± 6.7	59.9 ± 9.6

Values are mean ± SEM

Correlations for individual subject scores of total sleep time were high between visual scorers and the wireless technology



The mean epoch by epoch agreement was 84% between visual scorers and 75% and 73% between the wireless system and the visual scorers

		Visual Scorer 1			
		Wake	REM	Light	Deep
Visual Scorer 2	Wake	1683	72	334	4
	REM	3	1741	69	0
	Light	179	184	5591	34
	Deep	0	0	924	752

		Visual Scorer 1			
		Wake	REM	Light	Deep
Wireless System Neural Network	Wake	1184	206	175	2
	REM	197	1378	342	0
	Light	435	343	5472	188
	Deep	46	51	881	600

		Visual Scorer 2			
		Wake	REM	Light	Deep
Wireless System Neural Network	Wake	1159	171	235	2
	REM	223	1275	412	1
	Light	627	300	4872	626
	Deep	62	48	421	1047

Cohen's Kappa statistics indicate medium effect size agreements between visual scorers (0.75), consistent with prior research, on agreement between scorers from different laboratories (1), and medium effect size agreements between visual scorers and the wireless technology (0.59 and 0.57)

(1)Norman et al. Sleep. 2000;23:901-8.

Conclusion:

Ongoing and additional data collection and analyses are needed to further evaluate and validate the wireless system. The wireless system shows promise as a low cost, portable, easy to use, sleep monitoring technology that has advantages over existing ambulatory technologies to measure sleep.

Acknowledgements:

Ben Rubin and Paolo DePetrillo pioneered the wireless and neural network technology. Research supported by Axon Labs, Inc., Newton MA