Screening of Pediatric Sleep-Disordered Breathing With a Contact-Free Under-The-Mattress Sensor

M. Yizraeli Davidovich MSc.[1], Z. Shinar Ph.D.[1], D. Argaman MSc. [1], A. Tal MD [2]
[1] EarlySense Ltd. Ramat Gan Israel; [2] Soroka Medical Center, Faculty of Health Sciences, Ben-Gurion University of the Negev, Beer Sheba, Israel

Introduction

Contact-free measurement of sleep and sleep disordered breathing (SDB) in children may simplify screening, and allow unobtrusive home testing. In this study, we tested a contact-free system, previously validated for sleep in adults (Ref. [1]), that is based on a piezoelectric (PE) sensor placed under the mattress, and accurately measures heart rate, respiration waveform, and movement.

The aim of this study was to evaluate the accuracy of this contact-free PE system compared to polysomnography (PSG) in measuring pediatric sleep and SDB.

Methods

Children referred to a sleep study with suspected SDB, underwent full over-night PSG in a sleep laboratory, and were simultaneously measured with the PE system (EarlySense, Israel). The PE measurement was done using two sensors (placed under the thorax area and the abdomen area), and the sensor with the higher total signal intensity was chosen for comparison with PSG. Sleep scoring and Apnea-Hypopnea-Index (AHI) detections of the PE contact-free system were compared to PSG-based manual scoring of an expert sleep technologist, done according to AASM guidelines.

Demographics

Twenty eight children (17/11 male/female); ages: 2-13 years, 4.9±2.7 (mean ± standard deviation); with BMI of 14-22 (16.4 ± 2.0), number of apnea/hypopnea events of: 0-42 (9.4 ± 10.6), and AHI of 0-6.9 (1.4 ± 1.6) were included.

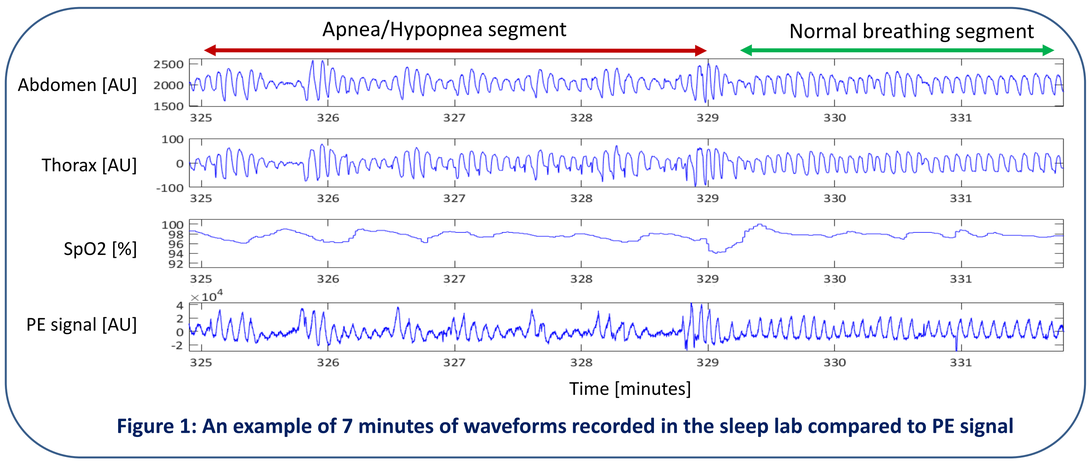

Figure 1: An example of 7 minutes of waveforms recorded in the sleep lab compared to PE signal

Results

Figure 1 shows a comparison of sleep lab recordings and the PE system (lower panel). The upper 2 waveforms are from RIP belts on the abdomen and thorax, 3rd panel is the pulse oximeter, and 4th panel is the waveform received from the PE system. During the 7 minutes, shown in the figure, the patient had respiratory events that are apparent in all waveforms (left side), as well as normal breathing (right side). The contact free sensor closely follows same breathing patterns at all times.

For each epoch, the sleep stage attained from PSG was compared to the stage of the same epoch obtained from the PE system, allowing one epoch shift (before or after).
Table 1 reveals a wake sensitivity of 87.9%, a REM sensitivity of 48.8% and a non-REM (NREM) sensitivity of 79.6%.

Table 1		Gold standard		
		WAKE	REM	NREM
PE system	WAKE	3866 **87.9%**	633 **13.9%**	1756 **10.1%**
	REM	112 **2.5%**	2218 **48.8%**	1777 **10.2%**
	NREM	421 **9.6%**	1693 **37.3%**	13811 **79.6%**

Table 1: Confusion matrix of the epoch-by-epoch comparison of wake, REM and NREM sleep stages.

Table 2 shows the same confusion matrix, collapsed into two stages – sleep and wake. It shows a sleep detection sensitivity of 89.1%, wake detection sensitivity of 87.9%, and accuracy of 88.9% for the PE system.

Table 2		Gold standard	
		WAKE	SLEEP
PE system	WAKE	3866 **87.9%**	2389 **10.9%**
	SLEEP	533 **12.1%**	19437 **89.1%**

Table 2: Confusion matrix of the epoch-by-epoch comparison of wake and sleep.

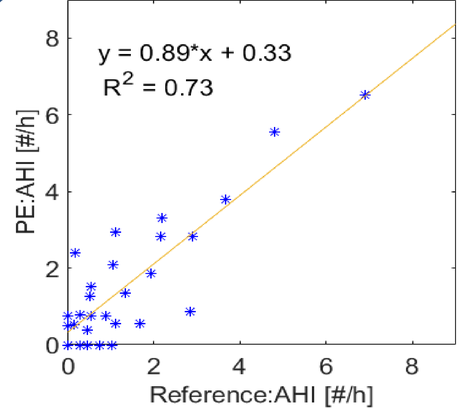

Figure 3: Linear regression of AHI calculated by the PE system vs. the PSG gold standard.

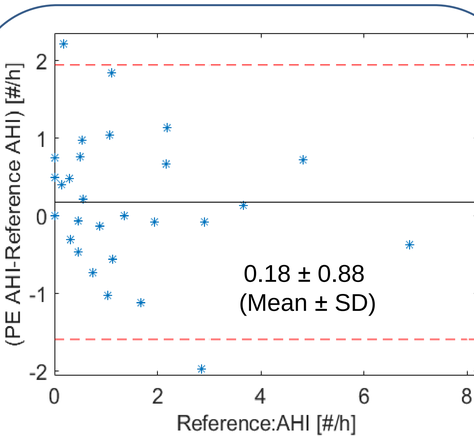

Figure 4: Bland Altman analysis of AHI calculated by the PE system vs. the PSG gold standard.

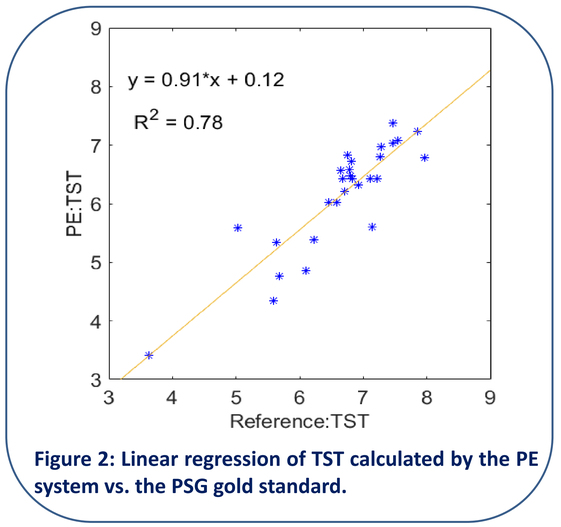

Figure 2: Linear regression of TST calculated by the PE system vs. the PSG gold standard.

As seen in **Figure 2**, linear regression of total sleep time (TST) calculated by the PE system versus the PSG gold standard showed a coefficient of 0.91 with R^2=0.78 ($p<0.01$).

Figure 3 shows linear regression of AHI calculated by the PE system versus the PSG gold standard with a coefficient of 0.89 and R^2=0.73 ($p<0.01$).

Figure 4 displays a Bland Altman analysis, which showed an AHI bias of 0.18 ± 0.88 (Mean ± SD). Bland Altman analysis for the total number of apnea/hypopnea events (not shown), showed a bias of -0.07 ± 5.45 (Mean ± SD).

Discussion

The contact-free under-the-mattress PE system shows promising results for the estimation of sleep and SDB in children. This system measures both – sleep/wake and apnea/hypopnea events, thus allowing an accurate AHI estimation. The analysis was done with an algorithm originally developed for adults. Adjusting the algorithm for children may further improve sleep/wake and AHI accuracy. In conclusion, the PE system may be used in the future for effortless screening of children for sleep disordered breathing for several consecutive nights, in their natural home setting.

References

1.Tal A, Shinar Z, Shaki D, Codish S, Goldbart A. Validation of contact-free sleep monitoring device with comparison to polysomnography. J Clin Sleep Med. 2017;13(3):517–522.

Acknowledgment: We wish to thank Shir Tal, Vlada Goizman and Yosef Schechter for their hard work.