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Screening Method to  
Determine Sleep Apnea

# Evaluation of Non-contact Ballistocardiography as a Screening Method to Determine Sleep Apnea

Srivyshnav K S<sup>1</sup>, Aashit Singh<sup>1</sup>, Gulshan Kumar<sup>2</sup>, Gaurav Parchani<sup>1</sup>, Vibhor Saran<sup>1</sup>

## Author Information

<sup>1</sup>Turtle Shell Technologies Pvt. Ltd, Bangalore, Karnataka, India

<sup>2</sup>National Institute of Mental Health and Neurosciences (NIMHANS), Bangalore, Karnataka, India

## Introduction

Sleep apnea is a serious sleep disorder that occurs when there is the absence of inspiratory airflow for at least 10 seconds causing irregular/broken breathing patterns. This results in drop in oxygen saturation in the blood being circulated in the body [1].

There are three types of apnea. The most common type is Obstructive Sleep Apnea (OSA), where the throat muscles relax causing obstruction in normal breathing. The second type is Central Sleep Apnea where the brain doesn't send proper signals to the muscles that control breathing. The third type is Complex sleep apnea syndrome which is a mixture of both obstructive sleep apnea and central sleep apnea [2]. Another variation of apnea is Hypopnea which is a result of abnormally slow or shallow breathing [3].

Sleep apnea is generally assessed by Apnea-Hypopnea Index (AHI) which is the number of apnea and hypopnea per hour. From a literature-based analysis, it can be seen that prevalence data for obstructive sleep apnea were available for 16 countries, of which 936 million adults aged 30–69 years (men and women) have mild to severe obstructive sleep apnoea and 425 million adults aged 30–69 years have moderate to severe obstructive sleep apnea globally. The number of affected individuals was highest in China, followed by the USA, Brazil, and India [4].

Major risk factors for apnea are - obesity, old age, large neck size, nasal obstruction due to allergies or sinus. If left untreated, sleep apnea can increase the risk of health problems such as - high blood pressure, stroke, heart failure, diabetes, depression, worsening of ADHD and headaches. Undiagnosed OSA is also associated with increased likelihood of hypertension, cardiovascular disease, stroke, daytime sleepiness, motor vehicle accidents, and diminished quality of life [5]. Maria R. Bonsignore et. al. also found OSA had 80% comorbidity with other lifestyle diseases [6].

Obstructive sleep apnea (OSA) has the highest prevalence, from 13% to 33% in men and from 6% to 19% in women. However, these numbers are underestimated and are likely to grow as they are closely associated with obesity and advancing age [7].

Kevin J. Finke et. al. also reported sleep apnea as a highly underdiagnosed disorder with nearly 90% people suffering from the same in the USA going undiagnosed [8]. Apnea can be an indication to a bigger health risk which could be avoided with early detection.

The gold standard to detect and assess sleep apnea is Polysomnography (PSG) which is performed overnight on subjects in a resource-intensive specialised sleep center which require the subjects to wear encephalography (EEG) electrodes, oronasal airflow sensors, thoracic and abdominal respiratory inductive plethysmography (RIP) belts, electrocardiography (ECG) sensors, an oxygen saturation finger-clip sensor, a body position sensor, chin and leg electromyography and electrooculography sensors over a full night. This setup is highly obtrusive for the subject and hampers a normal night's sleep. Moreover, the PSG procedure requires well-trained staff for analysis and is a costly process [9].

This resource intensive procedure of PSG has led to a constant search for a simpler, less intensive and intrusive method to screen for sleep apnea first which could later recommend PSG to the subject based on the severity of the screening test.

Ballistocardiography is a promising technique which is a non-invasive method based on the measurement of the body motion generated by the ejection of the blood at each cardiac cycle [10]. This can be used to overcome the challenges of the PSG system in a non-invasive manner.

BCG can not only be used to measure the micro body motions produced during each cardiac contraction [11], but also detect breathing, snoring and limb movements [12, 13] and moreover it can be made to work in a contact-free and non-wearable manner given a medium that can propagate body vibrations, such as when placed on a solid surface under a mattress, while a subject is lying over it.

## Method

Type 1 and 3 PSG studies were conducted on participants of this study where participants of Type 1 PSG study slept in a sleep laboratory while Type 3 PSG study participants slept at their home. To capture respiratory data from PSG, nasal thermistor and 2 Respiratory inductance plethysmography (RIP) bands were placed on the chest and abdomen. SpO2 monitor was placed on the fingertip of the participants while they slept. BCG data was captured using a device called Dozee [14, 15] which comprises a mesh of Polyvinylidene-fluoride (PVDF) vibroacoustic sensors placed under the mattress to capture micro- and macro-vibrations produced by the body when an individual is lying over it.

Figure 1 shows an apnea episode in the signals from the PSG signals (Nasal Airflow, Chest and Abdomen Respiratory Effort), as compared to BCG signal.

The respiratory signal from the PSG system was manually tagged for apnea events by a sleep expert, while events from BCG were captured by a proprietary algorithm developed by us.

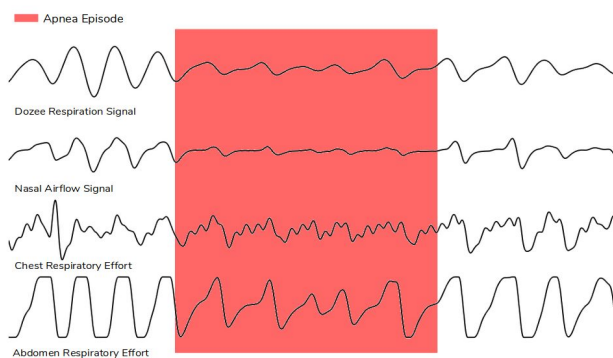


Fig.1 Comparing Episodes evident from Dozee signal and PSG system signals

Using the tagged apnea events the subjects were classified into 4 categories of apnea as shown in Table I, based on their AHI.

TABLE I. Classification of subjects based on AHI

Category	Range
No	0 - 5
Mild	5 - 15
Moderate	15 - 30
Severe	> 30

## Results

A total of 27 subjects participated in this study. Each of their apnea episodes were tagged in PSG signals by sleep scorer and BCG signal by our proprietary algorithm. Using the tagged apnea episodes AHI was then calculated for every subject. Out of 27 subjects, 6 were female and 21 were male, and the age range was from 24 to 75 with median age 48.

On comparing the overall event-to-event tagging, 83% of the tagged apnea episodes on BCG were in alliance with the apnea episodes tagged by the sleep expert using PSG data. The accuracy of the apnea episodes tagged on BCG signal was 82%.

The calculated AHI for the subjects using the episodes tagged by the sleep expert on PSG signals and our proprietary algorithm on BCG signal were highly correlated with a coefficient of determination (R2 score) of 0.91. Figure 2. shows the comparison between AHI tagged based on BCG signal to the PSG signals.

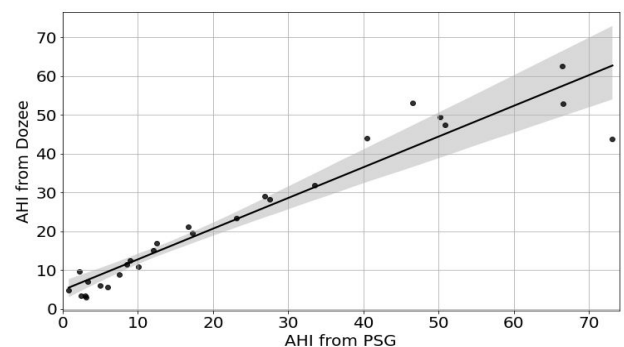


Fig.2 Correlation between the AHI from PSG and AHI from Dozee signal.

The subjects were further classified into 4 categories based on their AHI. It can be seen in Table II that sensitivity of classifying Moderate and Severe apnea is 100% (8 severe apnea and 5 moderate apnea). Furthermore, out of 8 mild apnea, 6 were classified

correctly, and out of 6 No apnea, 4 were classified correctly.

TABLE II. Confusion matrix between classification done using PSG signals and BCG signal

	Predicted No	Predicted Mild	Predicted Moderate	Predicted Severe
Actual No	4	2	0	0
Actual Mild	0	6	2	0
Actual Moderate	0	0	5	0
Actual Severe	0	0	0	8

## Conclusion

Sleep apnea is a highly underdiagnosed and overlooked disorder which can potentially lead to multiple serious health related issues. In this paper we proposed a cheaper, non intrusive method to detect sleep apnea using Ballistocardiography. We achieved a sensitivity and accuracy of 83% and 82% respectively while detecting each apnea episode while the R2 score of 0.91 was achieved on comparison of AHI from PSG signals and the BCG signal.

## Future Work


This study shows the effectiveness of BCG in screening for sleep apnea. This work can be extended to detect early development of apnea in people and its management. It can further be used to detect irregular breathing patterns such as Cheyne-Stokes, Kussmaul Breathing, etc. Research on the effect of sleep apnea on the cardiovascular system can also be enabled.

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## Turtle Shell Technologies Pvt. Ltd.

 #587, 1st floor, 9th A main,  
Indiranagar 1st stage, Bengaluru,  
Karnataka 560038

 [contact@dozee.io](mailto:contact@dozee.io)

  +91 96868 36933