Beth Israel Deaconess Medical Center

A teaching hospital of Harvard Medical School

Chung-Kang Peng, PhD
Director,
Center for Dynamical Biomarkers

Division of Interdisciplinary Medicine & Biotechnology

Associate Professor of Medicine
Harvard Medical School

K.T. Li Chair Professor
National Central University (Taiwan)

Visiting Chair Professor
National Chiao Tung University (Taiwan)

HUAWEI FIT Sleep Analysis Evaluation Report

We compared sleep analyses between a well-accepted ECG-based algorithm, called Cardiopulmonary Coupling (CPC) analysis, and the algorithm on HUAWEI FIT smartwatch. HUAWEI FIT and a single-lead ECG monitor were used simultaneously to record the signals during sleep on 200 Chinese subjects (87 males, 43.5%), with age range 18-45 years (median age 27 years).

Both algorithms classify sleep into four states: stable sleep (also denoted as "deep" sleep), unstable sleep ("light" sleep), REM sleep, and unknown state (due to bad signals). Classification by the CPC analysis is treated as the true events. The accuracy of the classification obtained by Huawei's algorithm are the following: Composite sleep duration 93.8%; stable sleep duration 88.8%; unstable sleep duration 90.7%; REM sleep duration 85.6%.

The results show that the classifications obtained by the HUAWEI FIT wristwatch and the ECG-based CPC analysis are consistent. Detailed study report can be found: http://reylab.bidmc.harvard.edu/FIT

荣耀手表 S1 睡眠分析测试认证报告摘要

本中心测试了荣耀手表 S1 的睡眠分析的准确度。心肺耦合分析（Cardiopulmonary coupling analysis, CPC）是一套广泛被医学界所接受的睡眠分析方法，许多文献已经证实此方法的临床价值，在此将作为本实验的对照方法，与荣耀手表 S1 睡眠分析的结果比对。

200位受测者（87位男性，43.5%；年龄18-45岁，中位数27岁）同时配戴荣耀手表S1与单导程心电图仪，监控整夜睡眠时的生理讯号。为了比对的一致性，在睡眠时间段内，区分为4种状态：1)熟睡、2)浅睡、3)快速眼动期(REM)、4)未知(讯号品质不佳)。在对比时，只有前三种状态会被考虑。荣耀手表S1睡眠分析与CPC的一致性结果如下：综合时长精度 93.8%；熟睡时长精度88.8%；浅睡时长精度90.7%；REM时长精度85.6%。

测试结果显示荣耀手表S1的睡眠状态分析与基于心电图的CPC分析有高度的吻合。详细报告参阅: http://reylab.bidmc.harvard.edu/FIT

哈佛医学院，CDB 中心主任

Chung-Kang Peng, Ph.D.

Suite KB-28
330 Brookline Avenue
Boston, MA 02215

(617) 667-7122
fax (617) 667-8052
cpeng@bidmc.harvard.edu

Comparison of Wristwatch-based and ECG-based Sleep Analyses

1. Background and Objective

The attention, memory and mood are strongly associated with a person's quality of sleep. Many studies have shown that various pathological conditions can be caused by poor sleep quality. Nowadays, the concept of sleep health management is becoming well accepted, and consumer sleep technologies are commonly utilized in mobile devices including high-end wristbands and smartwatches. However, the accuracy of sleep evaluation based on these wearable consumer devices has not been studied systematically. Most wearable devices on the market are entertainment-oriented, and cannot generate reliable sleep assessments. The objective of this study is to compare the result of sleep evaluation obtained by a wristwatch with the result from a well-accepted ECG-based sleep analysis, known as Cardiopulmonary Coupling (CPC). The CPC algorithm has been approved by FDA in the U.S. and China. The advantage of using the CPC analysis is that it has been extensively verified in sleep medicine, while at the same time wearing a compact one-lead ECG causes minimal disturbance to a test subject's sleep.

2. Method

2.1 Data samples

In this study, HUAWEI FIT device, a smartwatch which includes a photoplethysmography (PPG) sensor for heart rate detection, was used. HUAWEI FIT also implemented a sleep analysis algorithm based on heart rate variability.

All subjects wear both HUAWEI FIT smartwatch and a single-lead ECG monitor to record their signals. All subjects were asked to recall their sleep for the test night, including 1) time for bed, 2) time to fall asleep (sleep latency) and 3) wake-up time in the morning. The bed time and wake-up time were used to define the start and end points for sleep time. The data from wristwatch and ECG recordings were extracted and analyzed by HUAWEI FIT sleep analysis algorithm and CPC analysis, respectively.

2.2 Subjects

Healthy subjects from three Chinese cities (Dongguan, Suzhou and Nanjing) were recruited in this study. Data from 258 subjects were collected. To exclude subjects with bad signals, we evaluate the PPG signal quality by the amount of misdetection of heartbeat (based on the PPG signal), and use the subset of 200 subjects with the best signal quality. Their gender distribution: 87 males (43.5%); and age range: 18~45years (median age 27yr). The subjects reported total sleep time (TST) ranged from 135 to 550 minutes (median TST = 405min).

2.3 Statistics

In this study, sleep was classified into four states: stable sleep (SS, also denoted as “deep” sleep), unstable sleep (US, also denoted as “light” sleep), REM sleep (REM) and unknown state. Only the first three states were used as outcomes, while the unknown states (mostly due to bad signal quality) were eliminated from both outputs. The classification by the CPC analysis is treated as the true events. To investigate the accuracy of the classification obtained by wristwatch, seven measures were calculated: composite sleep duration; stable sleep duration; unstable sleep duration; REM sleep duration; detection of stable sleep epoch (each epoch is 1 minute); detection of unstable sleep epoch; detection of REM sleep epoch.

Accuracy of detection is defined as (TP+TN)/(TP+TN+FP+FN)*100%.

TP: number of true positive; TN: number of true negative

FP: number of false positive; FN: number of false negative

Accuracy of duration is defined as $(1-|T_{PPG} - T_{CPC}|/ T_{CPC})* 100\%$
where T_{PPG} indicates the time duration derived from wristwatch-based analysis, and T_{CPC} indicates the time duration derived from CPC analysis.

Composite accuracy of duration is defined as

$$1 - \frac{D_{stable\ sleep} + D_{unstable\ sleep} + D_{REM\ sleep}}{2 * T_{total}},$$

where *D* indicates the absolute value of difference of T_{PPG} and T_{CPC}, and T_{total} indicates the summation of time duration.

3. Result

The median values of accuracy of six measures are the following:

- 93.84% for composite sleep duration
- 88.78% for stable sleep duration
- 90.71% for unstable sleep duration
- 85.62% for REM sleep duration
- 84.70% for stable sleep epoch detection
- 75.29% for unstable sleep epoch detection
- 81.12% for REM sleep epoch detection

The median of composite accuracy of duration is.

Our results show that the classifications obtained by the HUAWEI FIT wristwatch and the ECG-based CPC analysis are consistent.