A Comparison of Holter and Polysomnogram-Based Detection of Bed and Wake Times

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Abstract

To determine if bed and wake times can be determined from continuous ECG recordings in the elderly, PSG (polysomnogram), ECG channels were extracted and scanned on a Holter analyzer for N=56 participants (age 76±3) in the Sleep Heart Health Study who had 2 PSGs 5 years apart. Bed and wake times were determined from a combination of 5-min averagaed HR and HRV patterns and from HR tachograms of normal-to-normal intervals. Bed and wake times were also extracted from the PSGs. PSG- and HRV bed and wake times were compared via paired t-tests and correlation analysis. Correlations between PSG- and HRV-determined bed and wake times were ≤0.95. HRV-derived bed and wake times were slightly (4±7 min) earlier for and 5±11 min earlier the 2 PSGs, p≤0.001. Mean PSG and ECG-based wake times were closer (12±20s earlier, p=0.069 and 2±8 min later, p=0.049 for the 2 PSGs). Therefore, determination of bedtime and wake time patterns in large Holter cohorts without activity diaries is feasible.

1. Introduction

Large sets of 24-hour Holter recordings have been used for overall HRV measures. Assessment of night time measures of HR and HRV have generally been based on arbitrary times in bed ("night"), e.g., midnight to 6 AM. Activity diaries not generally available for these recordings. Holters can potentially provide information about sleep patterns and HRV during sleep in different populations.

Going to bed and getting up are associated with sharp changes in autonomic function. Becoming supine results is a decrease in sympathetic activity and an increase in vagal (parasympathetic activity). Respiration slows and becomes more stable. Heart rate declines sharply and vagally-modulated HRV increases. As a result, the HRV power spectral plot develops a clear high frequency power peak at the predominant respiratory rate. Usually, the low-to-high frequency power ratio (LF/HF ratio) also drops.

Getting up results in changes in the opposite direction. Sympathetic activity sharply increases and vagal control of the heart declines. Respiration becomes faster and more irregular. Heart rate increases sharply and the clear high frequency HRV peak disappears. Usually, the LF/HF ratio of HRV rises.[1,2]

These changes form the basis for identifying lying down and getting up times from Holter recordings. However, we have found that among elderly people, high frequency HRV is often confounded by increased randomness of heart rate patterns, complicating the identification of bed and wake times. When high frequency power is confounded, the LF/HF ratio is as well. At the same time, the Cardiovascular Health Study, which enrolled community-dwelling participants ≥65 years old, obtained about 2600 Holter recordings that could potentially be used to study relationships of sleep patterns and outcomes in this population.[3] Thus, to determine if this method will work in elderly, we compared HR/HRV based bed and wake times determined from the polysomnogram (PSG) ECG channel only with "lights out" and "wake" time determined from stored information or other signals on the same PSG in elderly adults. PSGs were obtained in at-home sleep studies.

2. Methods

N=56 randomly-selected participants (age 76±3, 19M, 37F) in the Sleep Heart Health Study (SHHS) with 2 overnight, at-home polysomnograms (PSGs) obtained 5 years apart were analyzed.[4] In 12 instances the recording began exactly at bedtime and in 16 the recording ended exactly at wake. The corresponding bed or wake times were excluded from the current analysis, leaving 100 recordings for bed and 96 for wake time comparisons.

PSG recording began 33±33 min (range 3min-2:32hrs) before bedtime and continued 22±50 min (range 3min-3:37 hrs) after wake. PSG bi-polar ECG channels were extracted and scanned on a GE MARS 8000 Holter analyzer (GE Medical Systems, Milwaukee, WI). Beat-to-beat files were imported into a custom-designed program (HRVInteractive) and bed and wake times were determined from a combination of 5-min averaged HR and HRV patterns. Results were verified from changes on hourly HR tachograms and 5-min HR tachograms were used to identify these times more exactly. All tachograms were plotted from normal-to-normal interbeat intervals only. Figure 1 shows the HRV Interactive screen for 5-min HR and HRV patterns for a 24-hour Holter. There is a consistent relationship between heart rate and HRV patterns which follow the expected pattern. Figure 2 shows the same display for a PSG. Bed and wake times can be determined, although this participant ended the recording within minutes of waking up. Bed and wake times can be estimated from HR patterns, but HRV patterns less clear. Figure 3 shows a one hour tachogram for the hour around bedtime for the same subject. Ten minutes of beat-to-beat HR are plotted on 6 parallel axes read from the bottom up. The mean HR for each 10-min segment is shown on the right hand axis. Bedtime is seen as a drop in heart rate and a much more regular heart rate pattern. Figure 4 shows the same HRV Interactive screen for a different participant who kept the recorder on longer after waking up. Again, although HRV parameters are less clear, HR patterns clearly indicate bed and wake times. Figure 5 shows the 6-line hourly HR tachogram for that participant and Figure 6 shows the 5-min period at around wake time.

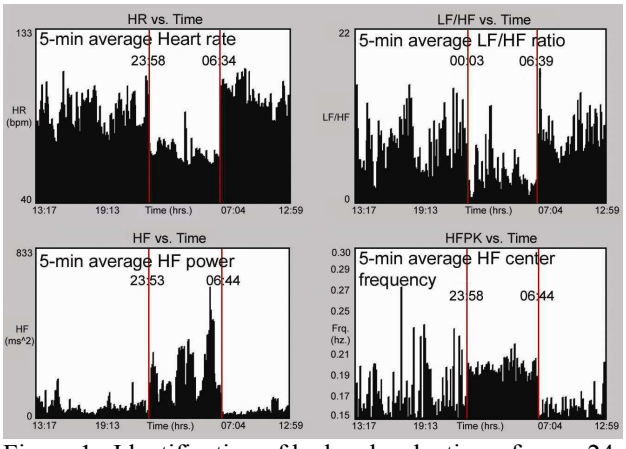

Figure 1. Identification of bed and wake times from a 24-hour Holter with clear autonomic changes.

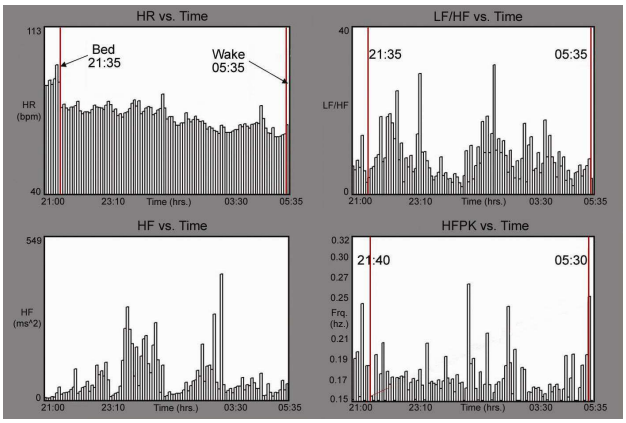

Figure 2. Identification of bed and wake times from a PSG. Wake time is near the end. Autonomic changes less clear.

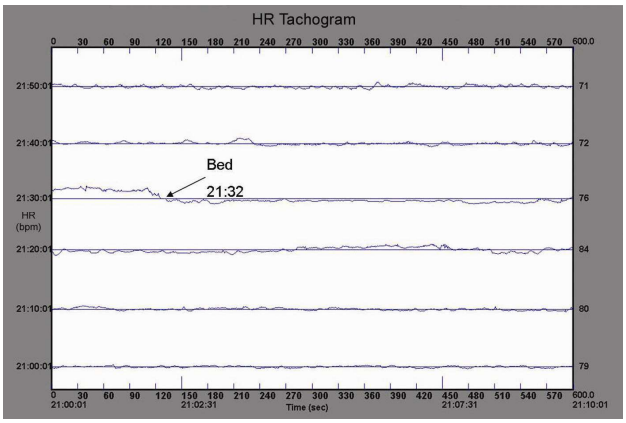

Figure 3. Identification of bed time from HR changes in 6-line, 10/min heart rate tachogram in same participant as Figure 2.

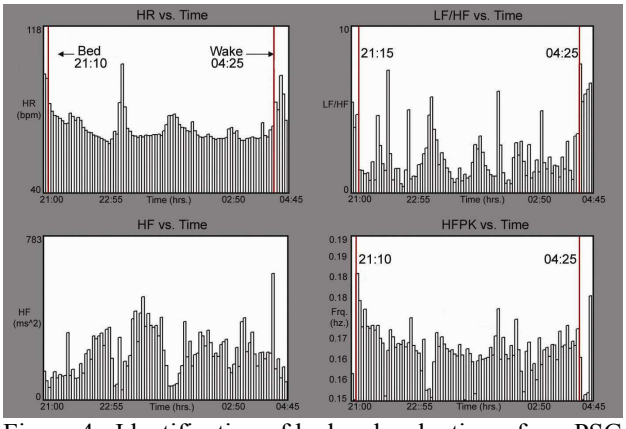

Figure 4. Identification of bed and wake times for a PSG for a different participant. Bed time is near the beginning of the recording. Autonomic changes less clear.

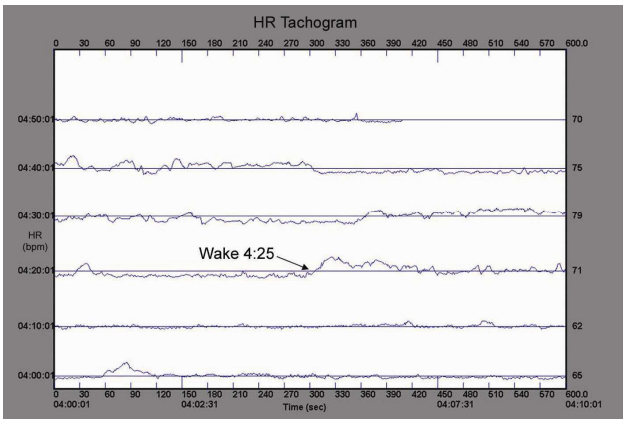

Figure 5. Identification of wake time from 6-line tachogram in same participant as Figure 4.

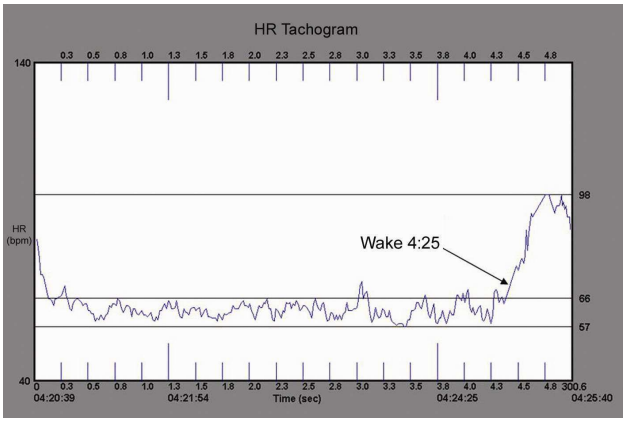

Figure 6. Identification of wake time from 5-min heart rate tachogram in same participant as in Figures 4 and 5.

Bed and wake times were also extracted from the PSGs using stored "lights out" times and wake times. If "lights out" times were not available bed times were determined from a combination of position changes, eye movement changes, and changes in leg EMG signals. PSG- and HRV-derived bed and wake times were compared via paired t-tests and correlation analysis using SPSSPC 14.0 (SPSS, Chicago, IL).

3. Results

Although the expected patterns in high frequency power, the LF/HF ratio and a clear center frequency of the high frequency band were not always seen among elderly SHHS participants, the combination of hourly plots, hourly tachograms and 5-min tachograms could still identify a bed and wake time for each participant. Correlations between PSG- and HRV-determined bed and wake times were high ($p \geq 0.95$). Mean HRV-derived bed and wake times were slightly (4±7 min) earlier than "lights out" times for the 1st PSG and were 5±11 min earlier than "lights out" from the 2nd PSG, $p \leq 0.001$ for both recordings. Mean HRV and PSG-based wake times were closer than bedtimes. HRV-derived wake time was 12±20s earlier than that derived from the PSG for 1st recording, $p=0.069$ and 2±8 min later than on the PSG for the 2nd recording, $p=0.049$.

4. Discussion and conclusions

Our results show that even among the elderly when bed and wake times based entirely on heart rate and HRV patterns are compared to precise bed and wake times based on signal from polysomnography, results correlate at >0.95 and differences between determinations are minimal. We have found similar results using 24-hour Holter recordings that have sleep wake diaries in both younger and older participants, but the current study provides a more precise test, because it is not subject to reporting error on the part of the participants. Thus, detection of bed and wake time from Holter recordings is feasible, in subjects in normal sinus rhythm, even if they are elderly. This supports the validity of studying bedtime and wake time patterns in large Holter cohorts, including the Cardiovascular Health Study, in whom activity diaries are not available. Further studies will determine if additional HRV measures would be useful for bed and wake detection.

It must be noted that bed and wake times, or the difference between them, are not the same thing as sleep time, although it is possible that a more refined HRV analysis might actually identify sleep onset and that possibility is being explored by other investigators. In a literal sense, there is no way to tell if the subjects are actually in bed, but we can determine that they are supine based on heart rate and HRV changes. Also, waking up and getting up were considered the same thing in this study, so what is actually being determined is time in bed.

Furthermore, in our studies of clinical populations and in older adults with Holter diaries, we have realized that in a minority of cases bed time and wake time are not as clearly defined as they are in younger people. Thus, we have observed subjects with clear sleep apnea patterns on Holter occurring 2 hours before they reported going to bed and subjects who went back to bed after they reported waking up in the morning. One can guess that those who had sleep apnea before bedtime were asleep, perhaps watching TV, but that did not "count" as bedtime. A strength of this method is that periods of supine rest and naps outside of normal sleep hours can also be characterized.

We conclude that HR and HRV-based identification of bed and wake times from Holter recordings is reliable and generally feasible even in older adults in whom there may be some cardiac autonomic dysfunction.

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