Feasibility of a Simple Method for Identifying Sleep Periods from Holter Recordings

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Abstract

To determine whether sleep periods can be identified from Holter-derived data using a combination of hourly average HR patterns and hourly spectral plots, Holter data from N=77 randomly-selected subjects with self-reported bed:wake (B:W) times were examined. N=50 were patients with a recent MI (C), 12 were younger subjects from a Holter quality validation study (Y), and 15 were subjects>65 years old from the Cardiovascular Health Study (O). N=18 (C) were excluded for a combination of abnormal circadian rhythm and abnormal HRV plots. The accuracy of hourly HR + HRV patterns to identify bedtime ± 1hr was: 100% (O), 84% (C), and 100% (Y). Hourly HR+HRV patterns identified wake-times ± 1hr 100% of the time for (O), 91% for (C) and 100% (Y). Identification of sleep periods from Holter data appears feasible in different groups using a simple algorithm. This method could permit detailed study of sleep periods in Holter cohorts where diaries are unavailable.

1. Introduction

During the daytime, heart rate is higher in order to facilitate performance of life's tasks. Conversely, at night, heart rate decreases as the brain, body, muscles, and nerves conserve energy and refresh themselves. Heart rate patterns can be monitored using Holter recordings. In addition, heart rate variability (HRV), which reflects cardiac autonomic modulation, can be calculated and plotted from Holter data. The high frequency HRV band, which is the amount of power in the 0.15-0.40 Hz band reflects parasympathetic modulation of heart rate, i.e., respiratory sinus arrhythmia (1). Parasympathetic modulation of heart rate increases markedly when subjects are supine and decreases markedly when they are upright (i.e., get up). In addition, the center frequency of the peak of the high frequency band permits estimation of respiratory rates which decline during sleep compared to waking. It seems intuitively obvious, therefore, that it should be possible to estimate sleep and wake times from Holter data, however this hypothesis does not appear to have been tested. We therefore attempted to estimate bed and wake times, within one hour, from the combination of hourly averaged heart rates and hourly averaged HRV power spectral plots in a set of Holter recordings, selected from different populations, in which there were self-reported bed and wake times.

2. Methods

2.1. Subjects

Subjects were randomly selected from our existing Holter datasets based on having self-reported bed and wake times. Fifty (C group) were patients with a recent (<1 month) MI from a study of HRV and mortality in depressed and non-depressed post-MI patients. These patients tended to be inactive and the majority were taking beta-blockers. Twelve (Y group) were selected from among the validation tapes for another study and were predominantly younger, healthy subjects. Fifteen (O group) were selected from the Cardiovascular Health Study, a population study of adults aged >65 years.

Heart rate and HRV patterns were examined for the presence of a clear circadian rhythm in heart rate, normal-appearing hourly HRV patterns and a visible high frequency peak in the power spectral plot during the nighttime. If none of these was present, the tape was excluded from the analysis. N=18 tapes in the C group, but none from the other groups, were eliminated for this reason.

2.2. Hourly heart rate analysis

Hourly averaged heart rates are included in a standard Holter report. Examination of the circadian pattern of heart rates permitted an initial estimation of bed time and wake times. Bedtime was associated with a relative and continuing decrease in hourly average heart rate and wake time was associated with a sharp increase in hourly average heart rates. Although the Holter report also provided the minimum and maximum heart rates for each hour, these did not prove to be especially useful. Figures 1A (from the O group), 2A (from the C group) and 3A from the Y group) provide examples of the circadian patterns of hourly heart rates plotted as histograms. Arrows indicate the bed and wake times selected in each case and the self-reported bed and wake times are indicated in the title.

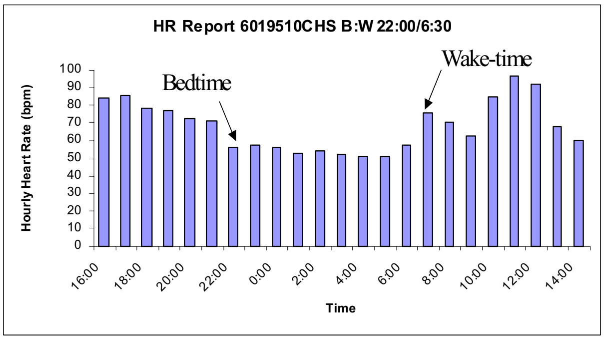

Figure 1A. Histogram of hourly averaged heart rates for an older subject.

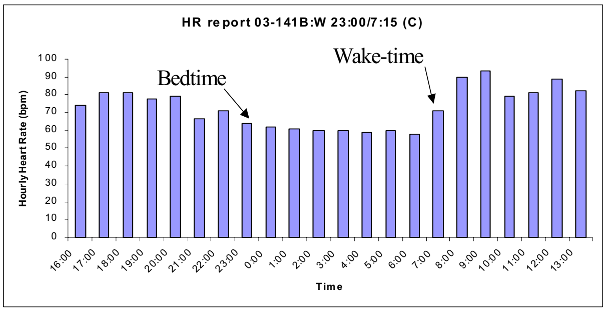

Figure 1B. Histogram of hourly averaged heart rates for a post MI subject.

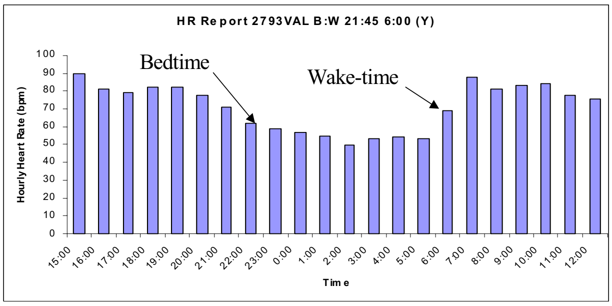

Figure 1C. Histogram of hourly averaged heart rates for a young subject.

2.3. Hourly power spectral plots

The hourly HRV plot permits detection of the sharp increase in vagal modulation of heart rate at bedtime and the sharp decrease in vagal modulation of heart rate upon getting up. The appearance and disappearance of these peaks are shown in Figures 1B, 2B and 3C. Each spectral plot corresponds to one of the previously-described histograms, i.e., Figure 1A to Figure 1B, 2A to 2B, 3A to 3B.

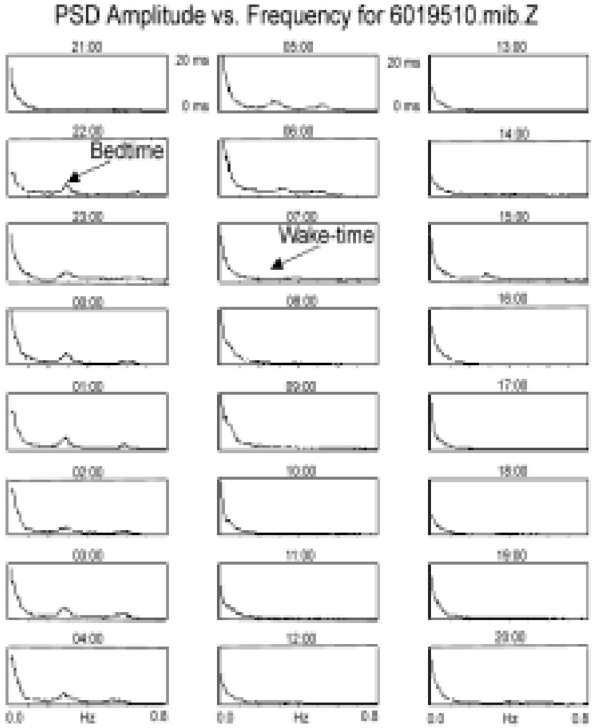

Figure 2A. Hourly power spectral plots for an older subject.

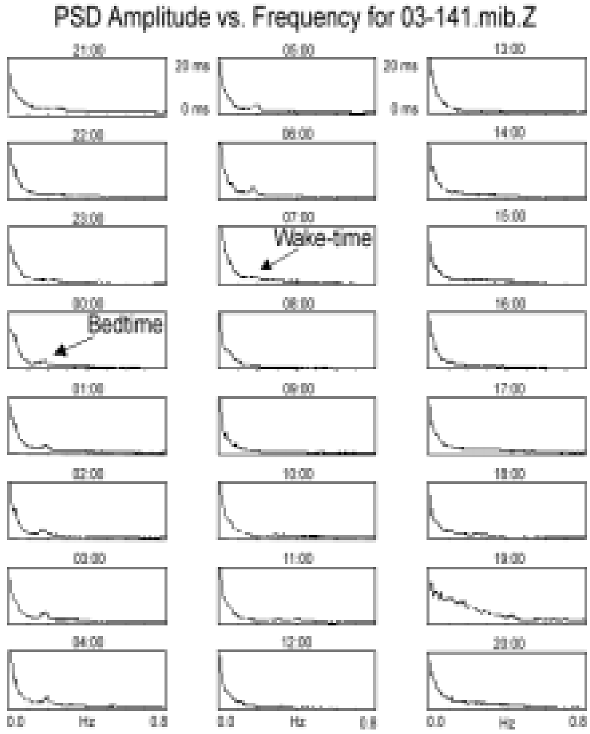

Figure 2B. Hourly power spectral plots for a post MI subject.

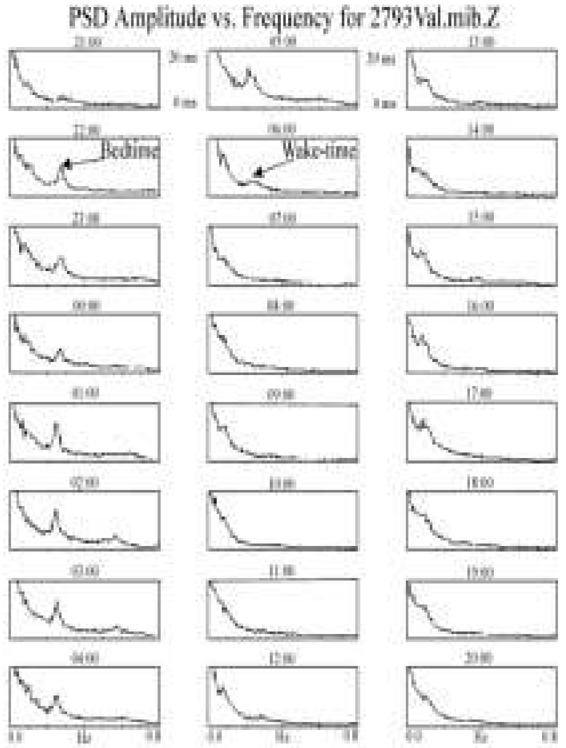

Figure 2C. Hourly power spectral plots for a younger subject.

Although not visible in any of the plots shown here, peaks in the VLF band (0.003-0.04 Hz) which reflect sleep apnea sometimes appear and can help identify sleep periods. Also, in some cases, a broad HF band peak, usually with a higher center frequency, was seen which became far narrower with a lower center frequency at bedtime. Presumably, the subject was lying down, but not asleep during this period.

2.4. Combined heart rate and HRV analysis

When heart rate and HRV-based estimates of bed and wake times were not consistent, we combined both results into a "best-guess" estimate. Also, when heart rate values were indeterminate, we used HRV results only to estimate bed and wake times.

2.5. Detailed analyses of discrepancies

To further understand why discrepancies between self-report and HR and HRV based estimates of bed and wake times occurred, in cases where differences were more than one hour, a detailed analysis of heart rate patterns was undertaken using tachograms of beat-to-beat heart rates *vs.* time. In some cases, there appear to have been multiple sleep periods, i.e, the person got up and then went back to bed, reporting the first time as wake time. Similarly, especially among the cardiac patients, subjects appeared to have been supine, and even asleep, for hours before self-report bedtimes. One subject reported going to bed but may not have actually fallen asleep until 1-2 hours later. In one case there appears to have been a systematic 1-hour error, either in the time of the hook up or in self-report.

3. Results

As can be seen from Table 1 on the next page, in most cases, Holter-based patterns identified bed and wake times with great accuracy. However, HR patterns were indeterminate in several cases. In general, HRV patterns provided clearer information about bed and wake times, but using both provided the best estimate. Also, as can be seen from the Table, and from the exclusion of 18 post-MI patients from the analysis, estimation of bed and wake times in a very sedentary population with a recent MI and high prevalence of beta-blocker use, which reduces heart rate changes in response to going to bed and getting up, is more difficult, although, we were able to account for most of the discrepancies using tachogram analysis.

4. Discussion

Results suggest that it is feasible to determine bed and wake times from hourly heart rates and HRV plots derived from Holter recordings in different patient populations. This may be useful in populations where sleep diaries are not available. HRV alone was more accurate than the heart rate alone. However, the combination of the heart rate and power spectral data was more accurate than either alone.

This method appears to be accurate, yet possible confounders should be considered when determining bed and wake times: (1) abnormal circadian rhythms of heart rate, (2) abnormal power spectral plots in which the HF component cannot clearly be determined, (3) little or no circadian rhythm of heart rate or HRV, and (4) supine inactivity before bedtime or after wake-time. In addition, when comparing self-report bed and wake times with Holter-determined values, the following could reduce the correspondence between them: (1) ambiguity over the meaning of wake and bed time, (2) rounding off of bed and wake times, (3) inaccurate self report or misreport, and (4) possible errors in the reported Holter start time.

Table 1. Correspondence between self-report and estimated bed and wake times in the different groups. (Number correct/number considered or percent).

	(O) N=15	**(C) N=32**	**(Y) N=12**
Bedtime			
Hourly HR	11/12	21/26	9/10
Hourly HRV	15/15	26/32	12/12
Combined	15/15	27/32	12/12
Combined %	100	84	100
Wake-time			
Hourly HR	13/13	27/32	12/12
Hourly HRV	15/15	29/32	12/12
Combined	15/15	29/32	12/12
Combined %	100	91	100

References

[1] Pomeranz B, Macaulay RJB, Caudill MA, Kutz I, Adam D, Gordon D, et al. Assessment of autonomic function in humans by heart rate spectral analysis. Am. J. Physiol. (Heart Circ.Physiol.)1985;17:H151-53

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