Importance of Monitoring of Emotional Stress and Physiological Functions of Humans during the Night Sleep

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Abstract: The diagnosis of disease and prescription of therapy are mainly realized through the control of physiological functions in humans during wakefulness. However, little attention is paid to evaluate the functional state of a patient in sleep. The efficiency of prescribed medicines is also determined in wakefulness. The effects of these drugs during sleep are usually out-of-sight of a physician. Human psychoemotional state during wakefulness is closely related to sleep. Various serious disturbances in physiological functions appear during the night sleep. They include cardiovascular disorders (hypertensive crisis, myocardial infarction, arrhythmias, stroke, etc.), which may cause sudden death. A large body of evidence shows that stress is followed by sleep disorders. They serve as a factor, which contributes to the development of stress. It should be noted that sleep is the major anti-stress factor. The vicious circle is formed, which can be revealed by a complex control of human physiological functions during wakefulness and sleep. We developed a new methodology and constructed an information-and-equipment device for monitoring of vital physiological functions of humans during sleep in a real everyday life. This approach holds much promise for the diagnosis of disease and evaluation of therapeutic efficacy.

Key words: Sleep, information medicine, medical devices, vital functions.

1. Introduction

The diagnosis of disease and prescription of therapy are mainly realized through the control of physiological functions in subjects during wakefulness. However, little attention is paid to evaluate the functional state of a patient in sleep. The efficiency of prescribed medicines is also determined in wakefulness. The effects of these drugs during sleep are usually out-of-sight of a physician.

Sleep is an important constituent of human vital activity, which determines the life quality, health, working capacity, mental activity, psychoemotional state, and resistance to emotional stress [1-4].

The introduction of polysomnography offered exciting possibilities to study the phase structure of sleep, to develop the normative criteria for human night sleep, and to evaluate the role of sleep as a stress adaptation factor in the human-environment system.

Cardiovascular abnormalities result from emotional stress of humans during wakefulness in a real everyday life. A large body of evidence shows that stress is followed by sleep disorders. They serve as a factor, which contributes to the development of stress. It should be noted that sleep is the major anti-stress factor. The vicious circle is formed, which can be revealed by a complex control of human physiological functions during wakefulness and sleep.

A normal physiological sleep is characterized by a series of consecutive phases. Each phase has a certain biological significance. The analysis and identification of night-sleep phases are based on the recording of EEG (electroencephalo-graph), eye movement, EOG (electrooculogram), breathing, BP (blood pressure),

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motor activity, and muscle tone.

A growing body of evidence illustrates the relationship between the individual psychoemotional state, character, level of emotional strain, sleep-wake cycle, and quality and phase structure of nighttime sleep. Emotional stress is followed by pronounced changes in the phase structure of sleep and impairs the cerebral cycles of sleep-wakefulness [5-11].

The individual features of phase structure of nighttime sleep were shown to be associated with the predisposition to various diseases, including neurotic, cardiovascular, and gastrointestinal disorders. It should be emphasized that precursors of these neurotic disorders appear first during the night sleep [12-14].

The standard methodology of somnology is usually used in medical practice, but does not allow us to perform a control of physiological functions during natural sleep under real, everyday home conditions.

This work was designed to develop a new methodology and to construct an information-and-equipment device for monitoring of vital physiological functions of humans during sleep in a real everyday life.

2. Results and Discussion

The information system developed in our study performs the following functions: identification and analysis of the phase structure of sleep, wake-up of a subject in the pre-determined optimal phase of sleep, and interruption of a long-lasting hazardous phase of sleep. Moreover, this system provides a cross-correlation analysis of the HR (heart rate) and RR (respiratory rate), as well as the processing of data on a PC (personal computer).

The information complex is a new portable microprocessor device, which consists of interrelated modules for the recording of sleep phases, ECG (electrocardiogram), EOG, and RR. Besides this, the complex has original software [15, 16] (Fig. 1).

Cardiac functions are monitored by a constant dynamic recording of the heart’s electrical activity (ECG) in humans under real everyday conditions. The device allows us to perform an individual programming of the upper and lower limits for HR. The maximum number of possible extrasystoles is set for each patient. Disturbances in the heart rhythm are accompanied by the delivery of an acoustic warning signal, which provides in-time medical treatment.

A cross-correlation analysis of HR and RR is performed with special PC software. The level of cross-correlations between HR and RR was shown to decrease significantly. These changes serve as a sign and consequence of disintegration of functional systems, which is associated with the emotional strain [16].

Phases of the night sleep are studied by dynamic recording of EEG and EOG. A cross-correlation analysis of these indexes is performed on an autonomic portable module. The information is transmitted to PC for a further analysis and storage.

Sleep occurs in the following main stages: REM sleep (rapid eye movement sleep), non-REM sleep (non-rapid eye movement sleep), and indifferent sleep.

The program involves a cross-correlation criterion, which allows us to distinguish between in-phase, out-phase, and non-correlating signals of EEG and EOG. The current phase of sleep is evaluated continuously over 20 sec (epoch of analysis). The samples of recording and analysis of night sleep phases are shown in Figs. 2 and 3.

Sleep is a heterogeneous and complex process. This process is characterized by cyclic periodicity and considerable between-group and individual variations. Sleep phases have various physiological signs and differ in the following parameters: HRV (heart rate variability), level of BP, RR and HR, EEG, EOG, and EMG (electromyogram), changes in body temperature; and hormonal reactions.

Parasympathetic influences on the heart usually prevail during sleep. These features contribute to a significant decrease in HR and systemic BP, increase in the standard deviation of RR intervals (SDNN), and
Importance of Monitoring of Emotional Stress and Physiological Functions of Humans during the Night Sleep

Fig. 1 Scheme of an information-and-equipment device for monitoring of physiological functions during the everyday night sleep.

A module for a correlation analysis of the heart rate and respiratory rate; B module for the registration and analysis of sleep phases, wake-up in the pre-determined phase of sleep, and interruption of a hazardous phase of sleep; C module of a security signal system for arrhythmia.
Importance of Monitoring of Emotional Stress and Physiological Functions of Humans during the Night Sleep

Fig. 2  Current record of sleep phases.
SLW periods of slow-wave sleep.

Fig. 3  Recording of phases in an eight-hour night sleep.
A Dynamics of the cross-correlation coefficient; RAP Diagram of various phases in the night sleep: period of rapid eye movement sleep; SLW periods of slow-wave sleep; B periods of indifferent sleep, upper region.
Development of respiratory sinus arrhythmia during sleep.

Activity of the sympathetic nervous system is highest in wakefulness. This index progressively decreases in sleeping, but increases during REM sleep. The sympathetic activity during tonic REM sleep is much higher than that in wakefulness. As differentiated from REM sleep, NREM sleep is characterized by the prevalence of parasympathetic influences [17-19].

Varoneckas and Zemaityte [12] showed that HRV in various stages of sleep serves as a reliable criterion for functional activity of the cardiovascular system. They examined the patients with CHF (chronic heart failure). HRV and stroke volume in patients with CHD (coronary heart disease) were much lower than in other patients during REM sleep. The authors reported that life-threatening arrhythmias most often occur during this phase of sleep.

Studies by Jovanovic [4] revealed a strong correlation between variations in HR and RR during sleep (correlation coefficient $r = 0.982 \pm 0.01$).

Khoo and Blasi [20] performed a comparative analysis of changes in HRV, BP, and RR in healthy awake and sleeping volunteers and patients with OAS (obstructive apnea syndrome). On the basis of their researches, a multifactor mathematical model was developed for the relationship between these indexes.

Following on from these studies, Ben-Tal [21] reviewed the existing mathematical and computer models for cardiorespiratory interactions and their changes during the transition from wakefulness to sleep.

The problem of correlations between HR and RR under normal conditions and during OAS was considered by Kabir et al. [13]. The significance of correlations between these indexes of cardiac function and breathing in OAS patients was lower than that in healthy volunteers. Cardiorespiratory correlations were shown to be associated with phases of sleep. Moreover, the level of correlations during rapid eye movement sleep was lower than that in slow-wave sleep.

The relationship between HRV and RR in OAS patients was also studied by Harrington et al. [14]. They showed the existence of strong correlations between these parameters. Quantitative values were identified to evaluate the sleep quality [14].

Sleep-disordered breathing in patients with heart failure was revealed by Kazimierczak et al. [22]. Previous observations by Gass and Glaros showed that patients with chronic headaches are characterized by the increased sympathetic tone and reduced parasympathetic tone (as compared to healthy volunteers) [23].

Much attention was paid to evaluate the interrelation between cardiovascular and respiratory indexes in children during the transition from wakefulness to sleep. These studies are of particular importance to solve the problem of sudden respiratory arrest in newborns during sleep. Ontogenetic aspects of the relationship between functional systems of the body (e.g., specific features of cardiorespiratory interactions at various stages of postnatal ontogeny) were described by Mrowka et al. [24]. The relationship between frequency characteristics of HR and RR in various phase of sleep were studied in infants (from birth to the age of 6 months). Significant changes were found in these interrelations. Bidirectional relationships in the first days after birth were transferred to a one-way relation at the age of 6 months (from the respiratory rhythm to the heart rhythm).

3. Conclusions

A large body of evidence shows the necessity of monitoring the cardiovascular and respiratory functions in humans during sleep to make a diagnosis and to prevent serious cardiovascular disorders, which are followed by cerebral stroke, myocardial infarction, and sudden death.

The severity of emotional stress should be
evaluated not only during wakefulness, but also in sleep.

The selection of potent pharmaceuticals to prevent cardiovascular and cerebral disorders and control of their effects should be performed by monitoring of vital physiological functions during everyday sleep.

We developed a new methodology and constructed an information-and-equipment device for monitoring of vital physiological functions of humans during sleep in a real everyday life [20]. This approach holds much promise for the diagnosis of disease and evaluation of therapeutic efficacy.

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Importance of Monitoring of Emotional Stress and Physiological Functions of Humans during the Night Sleep


